# Innovation Effects and Origins of Ego-Network Stability: The Hidden Dimension of Social Capital

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I believe the story which follows applies to my dissertation journey. Though different versions of this story exist, I borrow the one by Joel Osteen.

> One time, I heard about this wealthy man. He was known for being very eccentric and far out. One night, he was having a big party at his house. In his backyard, his swimming pool was filled with sharks and alligators. He announced to all the guests, "Anyone who will swim across my pool, I will give you anything that you want."
>
> In a few minutes, there was a big splash. He looked over and this man was swimming 90 to nothing, dodging the alligator, maneuvering his way around the sharks as frantic as could be. He made it to the other side just in the nick of time and jumped out totally panicked. The wealthy man came over and said, "I can't believe it. You're the bravest person I've ever met. Now what do you want me to give you?" The man said, "What I want more than anything else is the name of the person that just *pushed* me in!"

Unlike the story, I know the name of the person who pushed me in. Aks Zaheer is the best advisor and mentor any student can have and such has been his contributions to my intellectual development that I am short of words to express my gratitude. I thank him for recruiting me in the Ph.D. program. This deserves special mention because not many schools were willing to take risk given my lack of research experience. In addition, but for the countless hours he spent with me discussing the crafts of writing in general and the nuts and bolts of the dissertation in particular, I would not have been able to make it. Despite my complete ignorance of the process (further aggravated by my introverted nature), Aks never misjudged my ignorance for arrogance. He replied to my emails even when I least expected him to do so (e.g., even when he was in transit). Aks was generous with his advice on research, family, and job search. He has been a great mentor and coauthor.

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## Abstract

Much research has shown that firms' ego-network configurations, i.e., structural holes or network closure, help them achieve superior innovation outcomes. However, little is known about how overall ego-network stability affects innovation. In this two-part dissertation, I first argue that in the alliance network context the stability is detrimental for the focal firm's innovation performance. Moreover, firms are affected differentially by the stability depending on whether they span structural holes and on whether their inventive activities are geographically concentrated. Spanning structural holes mitigates the negative effect of ego-network stability whereas the geographic concentration of firms' inventive activities further worsens the negative relationship. Next, I develop propositions about the origins of firms' ego-network stability. I limit my theorizing in this case to structural hole stability or the stability of open structures only, with special focus on the embeddedness of alliance brokerage structures in geographic and network community space. I argue that the stability of network structures increases with the geographic distance between member firms. In contrast, I hypothesize that member firms' location in different network communities has a negative effect on the stability of networks. I empirically test my propositions regarding the (ego-network) stability-performance relationship using 198 biopharmaceutical firms headquartered in the U.S. over a 21-year period from 1985 to 2005. My estimation sample for testing the origins of structural hole stability comprises of 329 broker and 680 alter firms over 1985-2005, yielding 61,495 triad-year observations in the global pharmaceutical industry context. I find support for my ideas. I contribute theoretically by highlighting the importance of

network stability, a salient but lost dimension of social capital, for the focal firm's performance. My work has practical implications in terms of network rewiring and maintenance.

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# CHAPTER 1

## Introduction

In strategy research a firm's performance takes center stage (Gulati, Nohria, & Zaheer, 2000; Baum, Cowan, & Jonrad, 2014). Stressing interfirm heterogeneity, strategy researchers attempt to understand how and why a firm differs from another in performance (Nelson, 1991). The firm's performance, in this regard, is multidimensional in nature, with scholars focusing, among many other dimensions, on financial or accounting performance (e.g., Barnett, Greve, & Park, 1994), firm's market performance (e.g., Kale, Dyer, & Singh, 2002), survival and growth (e.g., Sapienza, Autio, George, & Zahra, 2006), CSR (corporate social responsibility) (e.g., Johnson & Greening, 1999), and innovation (e.g., Schilling & Phelps, 2007). For the purposes of this dissertation, I focus solely on innovation. The reason is that modern-day economic activities are becoming more and more knowledge intensive. Innovation in such knowledge-based environments is quite challenging but necessary – challenging because the knowledge relevant for innovation exhibits high rate of obsolescence, and necessary because innovation might be a key determinant for the firm's survival and performance (Utterback, 1994). The following excerpts from *the Economist* article aptly characterize innovation:

> Innovation has become the new theology…Yet there is still much confusion over what it is and how to make it happen… INNOVATION has become the industrial religion of the late 20th century. Business sees it as the key to increasing profits and market share. Governments automatically reach for it when trying to fix the economy… economists are still struggling to understand this most mysterious part of the wealth-creation process (*The Economist*, 1999).

Research into the 'how and why' of the differences in interfirm performance can be broadly categorized into two streams: One view treats the firm as an individual, atomistic actor, devoid of relations, and tries to explain the firms' conduct on the basis of the firm's resources (e.g., Barney, 1991) or on the basis of industries to which the firm belongs (e.g., Porter, 1979). The other view, taking a relational stance, emphasizes network resources as drivers of firms' performance (e.g., Gulati, 1999). Without a doubt, both streams have enriched and complemented the strategic management research. However, I, through this dissertation, intend to build on and contribute to the second stream, the 'embeddedness' view (Granovetter, 1985). My broader research objective is to a) improve the understanding of when and how interfirm networks affect firms' innovation performance, and b) how firms can make performance-enhancing network structures, if any exist, persist.

The social capital that firms derive from their ego-network structures of direct alliance relations acts as a resource. Along the lines of Bourdieu, I define social capital as "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (Bourdieu & Wacquant, 1992: 119). On the whole, social capital is a property of the collectivity (Burt, 1992). It helps produce goods and services, in my context innovation, similar to physical or human capital (Coleman, 1988: S98). Structures and the associated social capital set the scope of knowledge exchange (Cowan & Jonard, 2004; Krackhardt, 1992) by influencing the level and quality of inter-

organizational interaction and by serving as a gateway to critical resources such as information and knowledge (Gulati, 2007; Bourdieu, 1980; Kogut, 2000). The social capital embedded in the structural pattern of connections affects the firm's innovation performance (Nahapiet & Ghosal, 1998; Baker, 1990; Powell, Koput, & Smith-Doerr, 1996; Schilling & Phelps, 2007) across such diverse contexts as nanotechnology (Funk, 2014), biotechnology (Baum, Calabrese, & Silverman, 2000), computer (Sytch & Tatarynowicz, 2014), semiconductor (Podolny, Stuart, & Hannan, 1996), automotive (Dyer & Nobeoka, 2002), telecommunication (Majumdar & Venkataraman, 1998) and chemical (Ahuja, 2000).

Scholars generally agree that (egocentric) network structures, which the firm inhabits, are heterogeneous in their ability to generate social capital, which, in turn, explains interfirm differences in performances (Walker, Kogut, & Shan, 1997; Burt, 2000). Studies acknowledge that the flow of ideas and information varies based on the differences in the structural *configuration* of network "pipes" (Podolny, 2001), with different firms facing different costs and benefits of accessing information based on the configuration of their alliance network structures (Owen-Smith & Powell, 2004).

Two distinct structural configurations have dominated the structure-performance debate. First, closed structures (Coleman, 1990), in which all partner firms have alliance relationship with each other, generate social capital by engendering mutual trust and creating and maintaining group norms (Uzzi, 1997; Granovetter, 1985). Also, any partner firm is less likely to engage in opportunistic behavior because of the imminent censure

from other members and the related reputational risk (Coleman, 1988). The social capital from these closed structures fosters knowledge sharing by group members and subsequent integration, thus affecting innovation (Inkpen & Tsang, 2005; Adler & Kwon, 2002). Second, open structures or structural holes, the structural configurations in which the focal firm is connected with two unconnected alliance partner firms, generate social capital by providing access to non-redundant and a diverse set of ideas. The focal firm in these structures enjoys the undivided attention of the two partners vying for the same relationship, leading to better terms for knowledge exchange, catalyzing the performance of innovating firms (Hargadon & Sutton, 1997). Thus, notwithstanding the discussions about competing network configurations, extant scholarly debate has veered around to the key idea that the configuration of the ego-network structure, and the ensuing social capital, determines the focal firm's innovation outcomes.

In this dissertation, I draw attention to another relevant yet underemphasized dimension of the ego-network structure – network stability – in an attempt to build "a more general network model of social capital" (Burt, 2001:31). The original theorizing about social capital underscored both the *configuration* and the *stability* of the network of relations to understand performance differentials. As Coleman (1990:320) insightfully suggests:

> A second factor which affects the creation and destruction of social capital is the stability of social structure. Every form of social capital, with the exception of that deriving from formal organizations with structures based on positions, depends on stability.

Other scholars (cf. Dhanaraj & Parkhe, 2006) have emphasized stability's theoretical import. Insofar as the firms ('nodes') in the alliance network are in perpetuity homogenous in knowledge and in nature, i.e., in their willingness to share knowledge, a sole focus on the configuration of alliance network ties to evaluate the focal firm's innovation performance makes sense. However, the focal firm's network stability becomes salient when the nodes in its alliance network are heterogeneous and nodal identities matter. In this vein, in addition to the configuration, the *composition* of the network matters (Phelps, 2010).

Furthermore, focusing on network dynamics, studies have shown that structural holes are "fragile" (Stovel, Golub, & Milgrom, 2011), and their benefits are short-lived (Buskens & van de Rijt, 2008). Scholars also suggest that structural holes "decay" (Burt, 2002), and "timing" matters for their performance benefits, implying that stability (or the lack thereof) and the ensuing change in the composition of the ego-network structure may be relevant to the network's value-creating potential (Burt, 1992; Soda, Usai, & Zaheer, 2004; Baum, McEvily, & Rowley, 2012).

Stability is usually seen as being positively related to performance in the alliance literature (e.g., Luo, 2005) because it reduces the alliance partners' costs of coordination and monitoring (Mjoen & Tallman, 1997) and enhances their knowledge transfer efficiency (Lee & Cavusgil, 2006). Along similar lines, the human capital literature argues that turnover negatively affects productivity (Osterman, 1987). Dees and Shaw (2001) show this detrimental effect of turnover due to the social capital losses resulting

from changes in social structures. Thus, in certain contexts, including alliances, stability may increase performance.

However, there are reasons to believe that stability will negatively influence innovation. The firm's network stability and the ensuing continual information flows among the focal firm and its partners over time could make knowledge less valuable because of increased similarity in their knowledge bases, reducing the knowledge recombination potential and, thus, innovation. In sum, stability might have a dark side when it comes to innovation performance.

The first objective of my dissertation is to bring stability back in theories of (egocentric) network structure-conduct-performance. In light of this emphasis, in Chapter 2, I attempt to explicitly define network stability and articulate its importance as a theoretical construct. In order to do so I integrate scholarly articles in which stability is either discussed explicitly or alluded to. Drawing on Burt and Merluzzi's (2016) measure of network churn, I propose a fine-grained measure of network stability. To delineate how stability affects the focal firm's innovation performance, I investigate the outcomes of ego-network stability in the alliance context, arguing that the stability reduces the innovation advantages of the focal firm. I further investigate two contingencies, namely, the structural holes spanned and the geographic concentration of the inventive activities of the focal firm, that moderate the detrimental effects of ego-network stability on innovation. The focal firm may be able to limit the negative effects of stability on innovation by spanning structural holes in its alliance portfolios whereas the negative

effects are worsened when the focal firm's inventive activities are geographically concentrated. I empirically test and find support for these hypotheses using 198 biopharmaceutical firms headquartered in the U.S. over a 21-year period from 1985 to 2005.

The second objective of my dissertation is to examine the origins of ego-network stability. In Chapter 3, I develop propositions about what determines the stability of open structure configurations or structural holes. My switching from the stability of the overall ego-network in the prior discussion to the stability of open structural configurations needs further justification. First, I show in Chapter 2, among other things, that though network stability reduces innovation, open network configurations or structural holes help mitigate this negative relationship. As a follow-up study, I believe it makes sense to look into what makes these performance-enhancing open structure configurations persist. Second, most research has found a positive relationship between structural holes and performance both at the individual and at the firm levels of analysis. At the same time, scholars have suggested that structural holes or brokerage structures are "fragile" (Stovel, Golub, & Milgrom, 2011) and that structural holes "decay" (Burt, 2002). Searching for ways to enhance their stability is worthy of attention. Third, inclusion of the overall network would have necessitated an enormous amount of time and effort to collect additional fine-grained data such as the exact latitude and longitude of partner firms, with probably not much theoretical traction beyond the findings from looking at the origins of structural holes.

I consider the effects of the embedding of interfirm alliance brokerage structures in both geographical space and in network communities to understand their persistence or decay. I argue that geographic distance between member firms increases the stability of open network structures or structural holes. Distance reduces information quality and quantity, making brokerage identification difficult, and imposes additional coordination and communication costs, affecting alters' expected value of new relationship formation and maintenance, hence stabilizing brokerage. In contrast, I suggest that brokerage triad firms' membership in different network communities exerts a destabilizing effect on brokerage because of inter-community competition. I test my hypotheses with 329 broker and 680 alter firms over 1985-2005, yielding 61,495 triad-year observations in the global pharmaceutical industry context. I show that both the distance between the two alter firms and the distance between the broker and the alter firm are salient in reducing the likelihood of brokerage decay. However, brokerage triad firms' location in different network communities increases brokerage decay.

In Chapter 4, I discuss key takeaways from my studies. Here I answer the so-what question for managers and researchers. I hope the readers find the manuscript an interesting read. I chose not to create a separate chapter for the empirical analysis and instead kept them together with my propositions because I believe both theory and empirics go better together as a unit to tell a richer coherent story. To the extent that my work is able to draw the reader's attention to the second important aspect of network structure, its stability, which has otherwise been relatively less studied with the dominant

focus being on the configuration of network structures, I consider this dissertation makes a contribution to the emerging literature on network dynamics and performance.

# CHAPTER 2

## Ego-Network Stability and Innovation Performance

Five months ago the stream did flow,
The lilies bloomed within the sedge,
And we were lingering to and fro,
Where none will track thee in this snow,
Along the stream, beside the hedge.
Ah, Sweet, be free to love and go!
For if I do not hear thy foot,
The frozen river is as mute,
The flowers have dried down to the root:
And why, since these be changed since May,
Shouldst thou change less than they.

-From *Change Upon Change* by Elizabeth Barrett Browning

Inter-organizational relationships are considered the prime determinants of firm innovation because of access to knowledge and R&D capabilities from network partners (Gulati, Nohria, & Zaheer, 2000). How firms structure their alliance network relationships is even more important in knowledge-intensive industries because of the rapid obsolescence of existing knowledge and the inability of firms to keep up with fast-paced technological changes on their own (Powell, Koput, & Smith-Doerr, 1996). Much network research has focused on the association between the structure of firm's relationships, the ensuing structural social capital (Nahapiet & Ghosal, 1998) and the focal firm's performance (Baum, Cowan, & Jonrad, 2014).

More specifically, a large number of studies have examined the configuration of ego's network or the structural organization of focal firm's direct alliance ties and, in turn, the focal firm's innovation performance using two ideal types, namely, structural holes (Burt, 1992) and closure (Coleman, 1990). A structural hole arises when the focal

firm has alliances with two other firms ('alters') that are not themselves connected, providing diverse, nonredundant, and timely information to the focal firm and, thus, improving its innovation performance (e.g. Hansen, 1999). The other ideal type, closure, represents a structure in which all partner firms are connected to one other through alliances, enhancing mutual trust and maintaining norms of group conduct (Uzzi, 1997). The social capital thus generated facilitates the focal firm's innovation via knowledge sharing by group members and subsequent integration (e.g., Schilling & Phelps, 2007). In sum, whatever the type, the main focus of extant work, for the most part, has been on the configuration of the (egocentric) alliance network structure and the resulting innovation outcomes for the focal firm.

I supplement this structural (or 'configurational') lens by suggesting that prior research may have underemphasized how the *stability* of the ego-network structure, a key ingredient in the original theorizing on social capital, may play the role of an overlooked factor in explaining the innovation outcomes of firms inhabiting these structures. I define network stability as the obverse, or complement, of 'network churn' (Burt & Merluzzi, 2016; Sasovova, Mehra, Borgatti, & Schippers, 2010). Stability reflects the extent to which the composition of the focal firm's ego network remains unchanged from one time period to the next (see pages 36-37 for a detailed description of my construct definition).

More generally, it is worth recalling that seminal scholarship on the role of social capital, the operant mechanism in networks, has underscored the importance of stability. According to Coleman (1990: 320), "a second factor [the first is structure] which affects the creation and destruction of social capital is the stability of social structure. Every

form of social capital…depends on stability." Burt calls for "a more general network model of social capital" (Burt, 2001: 31) and inclusion of stability is an important direction in this regard. More recently, Burt supports the contention noting that, "Stability cannot be taken for granted...Current answers to this question are typically little more than *assumptions* convenient for formal models or speculation from cross-sectional evidence" (2007: 101, emphasis mine). Dhanaraj and Parkhe (2006) also underscore the importance of network stability as one of the three network orchestration processes, besides knowledge movement and appropriability, to which a hub firm must pay attention in order to reap innovation benefits. However, how ego-network stability affects innovation outcomes mostly remains an open question.

The little work in which stability is either alluded to or explicitly mentioned, hints at the construct's relevance for the focal firm's performance outcomes in general and innovation performance in particular. For example, although global network properties such as the network's overall clustering coefficient or average network size might seem stable, research suggests that such apparent stability might disguise the continual churn occurring at the individual network level (Kossinets & Watts, 2006; Wellman, Renita, David, & Nancy, 1997), with recurrent changes occurring in an individual focal firm's ties (Moody, McFarland, & Bender-deMoll, 2005). Further alluding to these underlying network dynamics, scholars have suggested that structural holes are "fragile" (Stovel, Golub, & Milgrom, 2011), and their benefits fleeting (Buskens & van de Rijt, 2008). Scholars have also posited that structural holes "decay" (Burt, 2002), and that their value arises from "timing," implying that stability (or the lack thereof) and the resulting change

in the composition of ego's network structures may be relevant to their value-creating potential (Burt, 1992; Soda, Usai, & Zaheer, 2004; Baum, McEvily, & Rowley, 2012).

Extant work on stability in the alliance literature usually views stability as a positive (e.g., Luo, 2005). Stability reduces the coordination and monitoring costs (Mjoen & Tallman, 1997). It enhances knowledge transfer efficiency, thus facilitating learning (Lee & Cavusgil, 2006). Similarly, the human capital literature posits that turnover is negatively associated with productivity (Osterman, 1987). Dees and Shaw (2001) underscore the negative effect of turnover, and the ensuing change in social structures, due to social capital losses. Thus, in certain contexts, including alliances, stability may be an asset for performance.

However, there are reasons to believe that ego-network stability has a dark side in that the stability may negatively influence innovation at the firm level. The stability of the firm's network structure could make knowledge less valuable as continual information flows across the focal firm and its partners over time create greater commonality in their knowledge bases. Further, structural persistence promotes a deepening of inter-firm relationships because of enhanced trust (Gulati, 1995a). The resulting ease of communication and coordination may make knowledge transfer more efficient, but also promote similarity of knowledge resources across the partner firms and the focal firm, further reducing the innovation potential from knowledge recombination.

I also suggest that contingencies may influence the strength of the relationship of network stability to innovation. A focal firm's open structure – the structural holes in its network – allows it to access nonredundant and diverse knowledge. The information

benefits thus available might help attenuate the negative innovation effect of network stability. Conversely, the focal firm's geographic concentration or the location of its inventive activities in one country might enhance the negative effects of stability on innovation due to the lack of knowledge diversity. Compared to high concentration, geographic dispersion exposes the focal firm to heterogeneous knowledge environments from multiple countries, increasing the focal firm's recombination potential (Kogut & Zander, 1993; Hitt, Hoskisson, & Kim, 1997). In sum, I investigate the following questions: *How does ego-network stability affect a focal firm's innovation performance? Further, how does structural hole spanning and geographic concentration mitigate or aggravate the effects of network stability?* I note that most of the limited work on network stability has theorized about its *antecedents* (e.g., Stovel et al., 2011) and tested it with mathematical models or *individual* level empirical data (Burt, 2002). I theorize about and test the *consequences* of stability on innovation at the interfirm level.

Notable exceptions to the paucity of work on the structure-stability-performance link are Soda et al.'s (2004) work on the declining performance effect of structural holes bridged in the past, and Baum et al.'s (2012) research on the decreasing market share benefits of bridging ties with age. However, unlike my work, Soda et al. (2004) focus on holes spanned in the past relative to more current holes whereas Baum et al. (2012) emphasize the fragility of older bridging *ties*. My study differs from this prior research in two key ways. First, I construct a theoretical framework to explain the direct and contingent outcomes of the *stability* of the ego-network *structure* rather than compare the outcomes of past and current structural holes. Put another way, Soda et al. examine the

persistence of outcomes from the "memory" of a historically prior structural hole; I examine the outcomes of the persistence of *current* structures. Second, in contrast to Soda et al., or Baum et al., I evaluate the outcomes of the stability of the overall ego network, rather than its configuration as structural holes (Soda et al.) or as ties (Baum et al.). Specifically, I differ from Baum et al. (2012) by moving from the age of the *tie* to the stability of the network *structure*. Placing dyadic relationships in an ego network context allows me to "identify quite dramatic changes in seemingly stable relations" (Gadde & Mattsson, 1987: 29).

My paper also differs from Aral and Van Alstyne's (2011) diversity-bandwidth trade-off paper in at least three ways. Specifically, Aral and van Alstyne (2011) examine the success rate of job openings filled in the context of email exchanges among employees within a single firm. First, a critical assumption in their paper is that, "Given evidence suggesting the prevalence of weak ties in structurally diverse networks and the likelihood of increased information flow in cohesive networks due to motivation and exposure, the bandwidth of communication channels should be lower in diverse networks. Thus, network diversity and channel bandwidth should trade off such that greater network diversity is associated with lower channel bandwidth" (2011: 94). By their logic, the variation in channel bandwidth or volume of communication derives from the assumption that structural holes are comprised of weak ties. (Note that, according to Burt (1990), weak ties are not a necessary condition for structural holes to exist). I do not foresee this variation in my case because of the formal contractual nature of interfirm alliance ties. These formalized relationships are strong, by definition, from the very

beginning.

Thus, I do not focus on any specific configuration of the network structure, such as structural holes, nor on the strength of the ties, but focus instead on the stability of the ego-network structure in general in my theorizing and empirics. Relatedly, there is no trade-off between diversity and bandwidth in my setting not only because formal alliance ties are strong but more importantly, the diversity arises from the differences in composition of the alters over time, rather than from structural holes. For instance, I provide the example of ImmuCell in my discussion of the first hypothesis, whose two alters changed over time, suggesting greater diversity (and lower stability), even though the configuration of the structure stayed constant.

Second, Aral and Van Alstyne (2011: 103, 119) assume that each employee within the firm keeps providing diverse and novel information in perpetuity because as the authors posit, "…each bit of novel information represents a job opening…" (2011: 104). The novel information required to fill a job vacancy relying only on emails from employees within a firm in their case is qualitatively different and possibly less complex than the novel information required to innovate in a knowledge-intensive context relying on interaction between two or more profit-maximizing firms. Further, I argue that knowledge novelty from alter firms within alliance networks in knowledge-intensive industries diminishes over time due to rapid obsolescence. Thus, the nature of "novelty" or "diversity" and, more to the point, their dynamics, are so fundamentally different in my setting as to make comparisons theoretically moot.

Third, unlike job search, where a client provides quite specific job requirements,

the focal firm in my case initially has only a vague idea of the research problem in hand, with the steps needed to find an optimal solution even more ambiguous. Thus, the nature of the task (dependent variable) differs so completely (job vacancy fulfillment vs patents) that their theoretical framework, again, may not apply to my setting. Also, it is difficult to attribute the focal firm's innovation to any specific alliance because firms recombine ideas from multiple sources and have less incentive to acknowledge whatever they learned over and beyond that in the stipulated contract (because of IP concerns). In this regard, knowledge flow from the ego network that is relevant to the focal firm remains a much more complex phenomenon than that studied in the Aral and Van Alstyne paper, one that fundamentally modifies the theoretical underpinnings of the argumentation.

I empirically test my hypotheses using a panel of 198 U.S. firms in the biopharmaceutical industry over a 21-year period from 1985 to 2005. To control for the unobserved time invariant heterogeneity, and the fact that my dependent variable is a citation-weighted patent count *sans* self-citations, I use a Poisson fixed effects quasi-maximum likelihood estimator. Several tests support the robustness of my results.

In the following sections, I first theorize about the stability of the network structure and its negative effect on the focal firm's innovation performance. Next, I examine how the focal firm's structural holes ameliorate the negative effect of the relationship between stability and innovation. Thereafter, I investigate the role of the geographic concentration of the focal firm's inventive activity in enhancing (i.e. worsening) the negative effect of stability on innovation. Following this, I introduce my empirical context, the biopharmaceutical industry, and detail the methods I employ to test

my hypotheses. I conclude with a discussion of my results and implications for future research.

## THEORY AND HYPOTHESES

### Ego-Network Stability and Focal Firm Innovation

I begin my theoretical exposition with an illustration of how ego-network stability, and its obverse, network churn, differ from a more conventional assessment of structure that does not take into account the composition of the network nodes. Consider the illustrative example of ImmuCell Corp's ego network. In 1995, ImmuCell had alliance relationships with Univax Biologics and Carrington Laboratories, and with Center for Special Immunology and Carrington Laboratories in 1996. The two alter firms (Univax and Carrington; and Center for Special Immunology and Carrington) were unconnected with each other in both periods. A mere focus on structural *configuration* in this scenario risks painting an incomplete picture because of the change in the composition of the network partners over time (Halgin & Borgatti, 2012; Sasovova et al., 2010; Feld, Suitor, & Hoegh, 2007). Conventional wisdom might argue that Immucell's network structure does not vary in that structural holes spanned and degree centrality remain the same (Burt's constraint = 0.5; direct ties = 2) for both time periods. However, as is evident from the case, the *composition* of the ego network changed with Special Immunology replacing Univax over the two periods. At the same time, it is possible that the innovation outcomes of the structural stability measured in this way will also differ because even though the network structure is the same across the two time periods, the fact that one of the partners changes may further increase knowledge diversity for the ego

firm. The example underscores how stability, or its complement, network churn, is necessary to more fully understand the effects of network change.

As mentioned earlier, I argue that ego-network stability is likely a negative when it comes to the innovation-creation potential of the network. In the build up to this, my central hypothesis, I first present a set of arguments that spell out the efficiency-enhancing dimensions of network stability, before arguing the opposite for a net effect that is negative. Ego-network stability, by which I mean a network with all repeated partners, is likely to enhance the efficiency of interorganizational knowledge transfer through four mechanisms: routines, shared beliefs, strength of ties, and trust (Dyer & Singh, 1998). First, repeated interactions as a result of relational stability among the focal firm and partner firms lead to the development of interorganizational routines (Zollo, Reuer, & Singh, 2002), facilitating smooth coordination and cooperation. Second, with the passage of time, common language and shared beliefs and meanings, as well as standardized templates for knowledge transfer, develop as managers start to better understand the other party's behavior, language and beliefs, facilitating communication and mitigating conflict (Tortoriello & Krackhardt, 2010; Doz, 1996; Uzzi, 1997).

Third, stability imparts strength to the alliance relationships underlying the ego network via multiple interactions (Granovetter, 1973). Strong ties in the network structure in turn smooth the transfer of not only codified knowledge but also complex and tacit knowledge, permitting richer, and finer-grained, information exchange (Kotabe, Martin, & Domoto, 2003; Hansen, 1999; Reagans & McEvily, 2003). Fourth, frequent interactions over time inculcate trust (Gulati, 1995a; Gulati & Sytch, 2008; Zaheer,

McEvily, & Perrone, 1998; Hoetker, 2005). Trust, thus generated, facilitates coordination between the focal firm and its alter firms (Obstfeld, 2005) and reduces monitoring costs by inhibiting opportunism and mitigating conflict (Inkpen & Currall, 2004). Overall, stability enhances knowledge transfer efficiency (Dhanaraj, Lyles, Steensma, & Tihanyi, 2004), thereby possibly increasing innovation.

A contrasting view of the relationship between stability and the focal firm's innovation performance emerges when we consider how stability affects the knowledge diversity available to the focal firm through its network. Diversity, in general, in its various forms such as geographic diversity (Zhang, Li, Li, & Zhou, 2010), ethnic diversity (Nathan, 2015), science-based diversity (Feldman & Audretsch, 1999), employee diversity (Østergaard, Timmermans, & Kristinsson, 2011), top management team diversity (Wiersema & Bantel, 1992), R&D team diversity (Reagans, Zuckerman, & McEvily, 2004), and technological diversity (Suzuki & Kodama, 2004), has been shown to be a key ingredient in studies of creativity and innovation. Such diversity allows for knowledge recombination, a critical condition for focal firm innovation (Hargadon, 2002; Fleming, 2001; Henderson & Clark, 1990). Dissimilar knowledge available to the focal firm increases both the quantity and variety of potential combinations of ideas, enhancing the likelihood of finding innovative solutions (Utterback, 1971; Fleming, 2001). Van Wijk, Van den Bosch, and Volberda (2001) show that the breadth of the knowledge to which the focal firm is exposed makes the firm more likely to search for novel and related knowledge. In the network context in particular, emphasizing information diversity, Burt (1992: 48) in his exposition of structural hole theory states that

"information is the substance" in order to reap the performance benefits from the network structure. Similarly, Phelps (2010) finds that technological diversity, coupled with network closure, enhances innovation. In sum, "… while network structure matters, access to *heterogeneous* knowledge is…of greater importance for innovation performance" (Rodan & Galunic, 2004: 541, emphasis mine).

My conceptualization of the performance implications of network stability is consistent with social resource theory (Lin, 1982; 1990) or Gulati's (2007) network resource theory. Theories that focus on the configuration of network structure (e.g., Burt, 1992; Coleman, 1990) treat resource access as given in that alliance partners are assumed to be homogeneous and to contribute equally to the focal firm's innovation (Tortoriello, McEvily, & Krackhardt, 2014). In contrast, social resource theory emphasizes the role of resources that the focal firm can access from its network (Lin, Ensel, &Vaughn, 1981). Seen through a social resource lens, neither weak ties nor bridging ties *per se* impart network advantages, but whether the focal firm's partners have the resources the focal firm needs to fulfill its research needs and whether the focal firm can access such resources matters for deriving network benefits. In this regard, the nature of resources that the focal firm's social network makes available takes center stage. Social resource theory is a natural extension of Penrose's (1959: 75) analysis of the resource-based view of the firm in which "*heterogeneity* of the productive services available or potentially available from its *resources*…gives each firm its unique character."

However, network stability reduces the knowledge diversity that is available to the focal firm for generating innovation, even more so in the context of interfirm alliance

network, for three reasons. First, the "tapping points" of these interfirm relationships through which the focal firm, inhabiting the ego network, accesses partner knowledge over time are relatively restricted because alliance agreements typically cover only a part of the partner firm's knowledge base. Even this limited knowledge access is conditional on the motivation and ability of the partner firms' research professionals (Reinholt, Pedersen, & Foss, 2011), who are both rationally- and contractually-bound to not share any additional information over and beyond the stipulated agreement between the two firms. Thus, the focal firm has a small window of opportunity for accessing the social resource in that "initially" it is easier for the focal firm to absorb "relevant and easy-to-transfer knowledge" from partner firms (Schildt, Keil, & Maula, 2012: 1155). Further attempts to acquire knowledge from partners might entail further investments in the focal firm's time and effort, especially in R&D (Harrison, Hitt, Hoskisson, & Ireland, 2001). Therefore, the likelihood of innovation reduces over time compared to the period early in the life of the alliance when the focal firm can easily assimilate network resources based on its preexisting knowledge (Mowery, Oxley, & Silverman, 1996).

Second, in knowledge-intensive industries, uncertainty, knowledge complexity, and rapid obsolescence of technological knowledge make it almost impossible for the focal firm to innovate by relying on social resources from the same set of alliance partners. The reason is that partner inertia and idiosyncratic technological trajectories ensure that partners keep innovating in the same direction as they did in the past, thus making it detrimental for the focal firm to depend on the same partners for continued innovation (Schweizer, 2005; Eisenhardt, 1989).

For example, in the biopharmaceutical industry drug development is a complex process that requires amalgamating and updating knowledge from such multidisciplinary fields as "molecular biology, physiology, biochemistry, analytic and medicinal chemistry, crystallography and pharmacology" (Henderson, & Cockburn, 1994: 65). In this regard, alliances and, by extension, networks created at a particular point in time might lose relevance because the focal firm might face different knowledge requirements at different points in time. But network stability might create network "lock-in" (Gulati & Westphal, 1999). In this regard, network stability represents the "dark side" of social capital which puts the focal firm's adaptability to changing research needs at peril, thus negatively affecting innovation (Portes & Landolt, 1996; Gargiulo & Benassi, 1999; Gargiulo & Ertug, 2006). In contrast, network churn, by removing inefficient partners, frees up the focal firm's resources to be used for other innovation projects (Vissa & Bhagavatula, 2012).

Third, network stability might make any specific configuration of network structure sub-optimal. As relationships get stronger the focal firm and its partners are more likely to have similar redundant ideas (Granovetter, 1973). The development of partner-specific absorptive capacity (Dyer & Singh, 1998) makes the focal firm's and its partners' knowledge bases similar, reducing the combinatorial opportunities. Stability breeds familiarity among the focal firm and its alters, making the knowledge embedded in the network structure more redundant by promoting the smooth flow, and the repeated use, of ideas among member firms. Of course, these *ex post* knowledge homophily effects

might be slowed or limited by knowledge stock that is long lived, harder to learn, and by lower absorptive capacity (see e.g. Hall, Jaffe, & Trajtenberg, 2005).

One way to resolve the tension between the positive effects of stability on knowledge transfer efficiency and stability's eventual negative effects on information diversity benefits is to bear in mind that the underlying alliance relations that constitute the focal firm's ego network are formal in nature. The formalized nature of inter-firm alliance relations ensures that the ties are relatively strong from the very start. High-powered incentives (Williamson, 1985) make it likely that partner firms are induced to cooperate with the focal firm to fulfill the knowledge-sharing goals of the alliance (Locke, 1999). Given strong ties, network stability and the routines thus formed might not further enhance knowledge transfer efficiency beyond a point. Further, because knowledge rapidly becomes obsolete in fast-paced knowledge-intensive industries and because partner firms, like all firms, suffer from inertia (as mentioned earlier), it reduces the likelihood that partner firms continue to provide diverse knowledge elements over time. Supporting this argument, Hoang & Rothaermel (2005), contrary to their expectations, find that partner-specific experience negatively affects joint project performance in the biopharmaceutical industry.

In addition, partners in interfirm networks are often more calculative and more likely to exercise their bargaining power over the focal firm (Gargiulo & Ertug, 2014), reducing the focal firm's chances of gaining knowledge elements (Lavie, 2007). Thus, increased knowledge transfer efficiency at the alliance level might be a processual advance that does not necessarily translate into innovation derived from the ego network.

Other prior research also hints at these downsides. Moorman, Zaltman and Deshpande (1992) find that over time, focal firms' relationships are less valuable because they become "stale or too similar." In contrast, Baum, Calabrese, and Silverman (2000) find that network churn, characterized by additions of new partners, increases innovation performance in the Canadian biotechnology context. Holloway and Parmigiani (2016) in their study of construction projects show that repeated partnerships reduce profitability. Goerzen (2007) shows that firms quite often engage in repeated equity-based alliances, with lower economic performance for those who have more repeated partnerships. Overall, the suggestion is that stability reduces knowledge diversity.

In sum, I argue that, with network stability, the beneficial effects of communication and trust and the subsequent efficiency gains in knowledge transfer among the firms in the ego network might not provide enough novel knowledge elements for innovation. In addition, these effects are further weakened by the lowered innovation-directed knowledge diversity benefits of stable networks. Thus, I posit that:

*Hypothesis 1. Ceteris paribus, greater ego-network stability of a focal firm is associated with reduced innovation performance for the focal firm.*

**Contingent Effects of Structural Holes Spanning**

In the previous hypothesis, I posited that ego-network stability has a negative effect on the focal firm's innovation performance. However, if the focal firm spans structural holes in its network, prior theory and research contends that it gains access to both more information sources (i.e., alters or partner firms), as well as much diverse information, compared to firms that span fewer structural holes (Burt, 1992). The

arguments for why and how firms that span structural holes tend to generate superior innovation outcomes are well established, so I only briefly reprise them here. Structural hole theory posits that accessing disconnected alter firms (partner firms that are not themselves connected) enables the focal firm to tap into nonredundant knowledge and information diversity, which it can recombine to create innovation (e.g. Hargadon & Sutton, 1997). Also, firms spanning structural holes are able to receive information in a timely manner, view the world more holistically, and filter good ideas using the network as a prism (Burt, 2004; Podolny, 2001). Such benefits apply even more strongly in knowledge-intensive contexts in which technology keeps evolving.

Furthermore, for innovation, knowledge flows must occur among the focal firm's partners. One alter firm's bid to outdo the other may allow the focal firm to extract better terms for knowledge exchange from each of the alters. Thus, the power inherent in this network configuration facilitates beneficial knowledge exchange for the focal firm, and a nonredundant network structure allows the focal firm to quickly locate and retrieve the knowledge needed for recombination and innovation (Schildt et al., 2012).

Moreover, a network structure full of structural holes enhances the quality of information available to the focal firm because it is able to compare and contrast the veracity of information provided by the different alter firms. Also, alter firms vying for the focal firm's attention allow the focal firm to have more control over its alters, conceding the focal firm more favorable terms for knowledge generation and transfer. In sum, the focal firm that spans structural holes is able to harness a greater ability to arbitrage. The enhanced ability to arbitrage, to access diversity and nonredundant

knowledge allows the focal firm to mitigate the negative effects of stability described in the previous section because of the greater novelty, vision advantage and arbitrage possible via the structural holes that it spans (Rodan, 2010).

In contrast, access to fewer structural holes or structural closure in the network is likely to worsen the negative relationship between ego-network stability and innovation performance. In this case, lack of enough options to choose among different alters might constrain the focal firm's ability to arbitrage (Burt, 2004), further enhancing the negative effects of lock-in created by network stability. The focal firm might have to adopt a more conciliatory stance while negotiating terms of knowledge generation and transfer with alter firms. Stability and the ensuing repeat interactions limit the leeway of the focal firm because the alter firms might become aware of the focal firm's rent extraction techniques, unlike the case of focal firms spanning more structural holes, where increased competition among alters keeps their power at bay. Also, spanning fewer structural holes impairs the vision advantage of the focal firm as it may not be able to validate the accuracy of the information and not exercise the threat option as effectively in the case of deviant alter firms.

Taken together, I argue that when the focal firm spans more structural holes, the negative effects of ego-network stability on innovative performance are mitigated. Thus,

> *Hypothesis 2. Ceteris paribus, the greater the spanning of structural holes by a focal firm, the less negative the relationship between stability and the focal firm's innovation performance.*

**Contingent Effects of Geographic Concentration**

I further posit that the degree to which the focal firm is geographically concentrated in its inventive activities increases the negative effect of ego-network stability on the focal firm's innovation performance. Conversely, a focal firm with operations in different countries (low geographic concentration) benefits from four key knowledge advantages. First, multicountry presence offers it a more benevolent environment for innovation. Differences in culture, markets, and institutions translate into heterogeneity in knowledge elements across countries (Ghemawat, 2003). The reason is that within each country, innovation systems in general, and firms in particular, face different, idiosyncratic environments, thus leading to the development of unique technological trajectories (Ahuja & Katila, 2004). The diversity made available by multicountry knowledge environments is crucial in the innovation context because "a diverse background provides a more robust basis for learning because it increases the prospect that incoming information will relate to what is already known" (Cohen & Levinthal, 1990: 131). In contrast, the lack of a multicountry presence (high geographic concentration) prevents the firm from tapping into greater knowledge variety for innovation. The reason is that knowledge is well known to be sticky, geographically bounded and does travel easily across geographic boundaries (Jaffe, Trajtenberg, & Henderson, 1993).

Second, having operations in different countries allows the focal firm to learn from the best operating practices in different countries and handle complex transnational knowledge environments to search for market opportunities (Ghoshal & Bartlett, 1988;

Westney & Zaheer, 2008; Hitt et al., 1997). Unlike the focal firm with multicountry presence, the geographically-concentrated firm might lag behind in adopting the cutting-edge practices from multiple countries. Third, multicountry presence allows the focal firm to take advantage of employee diversity for innovation wherein employees educated at diverse technical institutions are more likely to enhance innovation performance (Østergaard et al., 2011). In this case also, the firm lacking in multicountry presence might have a lower recombination potential because of technological know-how similarity among its employees. Fourth, a presence in multiple countries allows the focal firm to engage in arbitrage in knowledge-related factor markets, such as by performing R&D in offshore locations, increasing the efficiency and effectiveness of its innovation-related activities (Zhao, 2006; Nandkumar & Srikanth, 2016). In contrast, the geographically-concentrated firm is less likely to engage in arbitrage because of the relative efficiency of factor markets within one location.

In sum, high levels of geographic concentration (low internationalization) make it less likely that the focal firm can take advantage of knowledge diversity. This lack of diversity is likely to aggravate the negative effects of network stability. Thus,

> *Hypothesis 3. Ceteris paribus, the greater the geographic concentration of a focal firm's inventive activities, the more negative the relationship between stability and the focal firm's innovation performance.*

# METHODS

## Data and Sample

I test my hypotheses with biopharmaceutical industry data. For the purposes of this paper, the biopharmaceutical industry consists of medicinal chemicals (SIC 2833), pharmaceutical preparations (SIC 2834), human diagnostics-- in vitro and in vivo (SIC 2835), and biological products, other than diagnostic substances (SIC 2836). This empirical context is apt for various reasons: The industry is knowledge-intensive and firms invest heavily in R&D (Henderson, 1994; Boland Jr & Tenkasi, 1995). Also, innovation and new product introductions are crucial to survive in this industry (Nerkar & Roberts, 2004). However, drug development is an uncertain process. Firms take, on an average, 12.5 years to develop a new drug (PhRMA, 2013). Only 0.02% of the total compounds from the discovery or pre-clinical testing stage get final approval as a drug (PhRMA, 2013). In addition, the total cost to develop one drug varies from $1.5 billion to $1.8 billion (DiMasi, Hansen, & Grabowski, 2003, 2008). Furthermore, as discussed before, drug development is a complex process that requires amalgamating and updating knowledge from such multidisciplinary fields as "molecular biology, physiology, biochemistry, analytic and medicinal chemistry, crystallography and pharmacology" (Henderson & Cockburn, 1994: 65).Uncertainty, high costs, knowledge complexity, and rapid knowledge obsolescence make the network a commonplace "locus of innovation" in this industry (Powell et al., 1996) because it almost impossible for firms to innovate only in-house (Schweizer, 2005).

Furthermore, pharmaceutical firms tend to patent the bulk of their innovations (Paruchuri, 2009; Levin, 1986), which is my dependent variable of interest. In fact, the biopharma industry is more prone to 'patent cliffs' –a phenomena in which a firm's revenue fall sharply (fall off a cliff) when one of its leading drug approaches its patent expiration date. For example, as soon as the patent protection for Pfizer's Lipitor expired on November 30, 2011, Watson Pharmaceuticals' and Ranbaxy Laboratories' generic substitutes became available in the market (*Time*, 2011). As a result, Pfizer's profit reduced by 19% in the first quarter of 2012. Similarly, Eli Lilly saw a decline of 15% in its sales volume on the patent expiration of Cymbalta and Evista. In contrast, Otsuka Pharmaceutical was able to avoid the competition from generic manufacturers by reinventing its blockbuster Abilify as a pediatric treatment drug besides its original use to treat bipolar disorder. Thus, patents play an important role in the pharmaceutical industry.

Using the SDC Platinum database as a baseline, I selected all firms in the global pharmaceutical industry, both public and private, which participated in alliances announced from 1980 through 2005. I further augmented this information with information from archival search using multiple sources such as *SEC-EDGAR*, *LexisNexis*, *Factiva*, and *Bloomberg* (Phelps, 2010). Few alliances exist before 1980, reducing the possibility of left censoring in the data. I used all alliance types because the alliance's scope is often understated, and innovative knowledge can come from any alliance (Schilling & Phelps, 2007). Next, I define the network boundary as follows: First, each pharmaceutical firm must have an alliance with another pharmaceutical firm (Rowley, Behrens, & Krackhardt, 2000). In case the alliance has multiple partners, extant

work constructs dyads based on all possible dyadic combinations of alliance partners (Lavie & Miller, 2008). In my case I determine how to deal with multiple partners on a case-by-case basis after carefully analyzing the alliance text. As an example, I reproduce below the alliance description from the SDC for Cambridge Biotech Corp, BioNebraska, and R&C Enterprises:

> Cambridge Biotech Corp., BioNebraska Inc., and R&C Enterprises have entered into an agreement to create a joint venture specializing in osteoporosis therapies…Under the joint venture agreement, Cambridge Biotech provided funding and drug delivery technology and BioNebraska and R&C provided the GHRF technology.

For this case, I created three alliances, namely one between Cambridge and BioNebraska, one between Cambridge and R&C Enterprises, and one between BioNebraska and R&C Enterprises. However, I take a different approach in the case of the multi-party alliance between Igen, Inc., Eisai Co., Ltd., and Boehringer Mannheim, GmbH whose alliance text I reproduce below from the SDC:

> Igen granted Eisai and Boehringer Mannheim GmbH a license to develop a clinical diagnostic system using its Origen technology. Eisai was granted the exclusive right to work with Igen to develop a system and market the products in Japan for the clinical diagnostic market. Mannheim was granted the license to develop instruments and assays for the centralized diagnostic market.

For this case, I created only two alliances, namely ones between Igen and Eisai and between Igen and Boehringer. From this specific alliance, I do not find any evidence of relationship between Eisai and Boehringer.

Second, each alliance itself must be in the pharmaceutical domain (Schilling & Phelps, 2007). Then, I aggregated all subsidiaries, joint ventures, spin-offs (50% or more

of the ownership), and business units at the ultimate parent level. In case a joint venture was a 50-50 venture, I assigned all alliances formed by the joint venture to both the parent firms. For example, TAP Pharmaceutical Products' alliances were assigned to Abbott and Takeda.

I further accounted for future name changes, reorganizations, and mergers and acquisitions (M&As) using multiple sources such as the *SDC Alliance Database*, *Directory of Corporate Affiliations, Who Owns Whom* and *Bloomberg*. Pharmaceutical firms change names to, among other reasons, reflect changes in their drug profiles and to deflect negative attention due to failed drugs or due to some external conditions beyond their control. For example, Isis Pharmaceuticals changed its name after Paris attacks in 2015 to Ionis to avoid any negative connotation of being a terrorist organization. A failure to consider such changes might inflate the number of firms in my sample, and, also, make my network structures 'artificial' in that two alter firms might be one and the same.

Some firms in my sample underwent multiple acquisitions. For example, Pacific Biotech was acquired by Eli Lilly in 1990 and, later, acquired by Quidel in 1995. I assigned alliances between Pacific Biotech and any other pharmaceutical firm before 1990 to Pacific Biotech, between 1990 and 1995 to Eli Lilly, and from 1995 onward to Quidel.

I was especially cautious about reverse acquisitions in which (mostly) a private firm in order to avoid the time and costs of the initial public offering (IPO) acquires a public company. In such cases the acquired public company is the surviving entity but in

reality the private firm has the controlling interest and manages the operations. For example, in the case of Access Pharmaceuticals and Chemex Pharmaceuticals merger in 1996, even though Chemex was the surviving entity, I treat it as the acquisition of Chemex by Access. The reason is that Access had 60% interest in the company and not otherwise. It is also consistent with the generally accepted accounting principles (GAAP) requirements.

In addition, I tracked each merger announcement through completion to ensure that the merger did not fell through post its announcement. In the case of 'merger of equals' in which two firms of roughly equal size merge to form a new entity, I assigned the combined alliance data to the new entity and updated further (post-merger) alliance information using the new entity. For example, in 1995 Pharmacia of Sweden and Upjohn of the US merged on a 50-50 basis to form Pharmacia and Upjohn. I assigned the combined alliances of these two firms from 1995 onwards to Pharmacia and Upjohn.

For arriving at an accurate empirical estimate of each alliance's duration, which most prior literature assumes away by adopting a five-year rolling window approach, I painstakingly created a hand-collected database with complete deal information using multiple archival databases including *SEC-EDGAR*, *LexisNexis*, *Factiva*, *Bloomberg Professional Terminal,* and *Mergent Online,* news sources such as *PR Newswire*, *Business Wire*, *PharmaTimes*, *Strategic Transactions :: Pharma & Medtech Business Intelligence*, *BioCentury*, and *Pharmaceutical Online,* trade journals such as *Japan Chemical Week*, and company websites, especially their timelines and news sections for major events such as NASDAQ listings. I removed alliances that did not actually get

created, and used a multi-pronged five-stage process to search for termination dates. First, for alliances that specified termination dates in my deal text database, I further accounted for alliance extensions or new alliances. Second, for open-ended alliances (the majority of my data), I used a keyword-based search using partners' names in combination with multiple variations of the word "termination," "end," "complete," "dissolve," "break" "withdraw," "leave," with or without drug or disease names and further checked for any alliance extensions or new alliances. Joint venture terminations were relatively easy to find using the names of joint ventures from deal texts.

Third, I used pharmaceutical compounds, disease areas or drug names from deal texts to search such databases as *Adis Insight* to help me identify possible reasons for the termination of alliances. If the trial or the drug was discontinued by the firm and no new alliances were formed between alliance partners, I treated the discontinuation date as the alliance termination date. Fourth, for every year since alliance formation I tracked its mention in SEC filings and annual reports' exhibit or agreement sections or followed the deal's progress using *Factiva*, until these reports did not discuss the deal anymore, which I then used as the termination date. I did not use this method when the deal was mentioned in only one year. Fifth, I checked for bankruptcies and mergers and acquisitions and verified if the deal still continued between the new partners to incorporate this new information. Taken together, these new data were used to calculate alliance duration. The sequence of actions that I spell out here are the progressive, cascading steps that I took if data on termination dates were unavailable in previous steps – i.e. I went to the next step only if I could not find data in the prior step.

In Appendix 1 at the end of this dissertation, I present a detailed step-by-step flowchart of how I determined termination dates, including the percentage of observations for which I could identify the termination date in each step. In addition, in Appendix 2 (also at the end of this dissertation), I provide further fine-grained detail about this process using real-world examples (cases) from my dataset for each of the steps mentioned in the flowchart. The cases selected for the detailed discussion are broadly reflective of the different ways in which I arrived at the termination dates. Together, the flowchart and the case examples provide fine-grained detail on the exhaustive and systematic process that I utilized to determine alliance termination dates. Given the exhaustiveness of my process, I am confident that these new data are well-reflective of actual alliance termination dates and form a sound foundation of my measure of ego-network stability.

I used this alliance duration information to construct undirected adjacency matrices consisting of dyadic alliance ties between firms for each year and further to create my network and alliance-based measures. This criterion resulted in 208 U.S. firms each with at least two direct ties and 1,379 firm-year observations. The reason for including firms with at least two direct ties is that I consider, in line with classic theory (Simmel, 1950), the triad rather than the dyad is the smallest social unit that still retains the distinctive properties of the network (Wasserman & Faust, 1994; Choi & Wu, 2009).

Furthermore, I collected U.S. patent data using multiple sources such as the United States Patent and Trademarks Office (USPTO) (bulk downloads using Google's data mirror), NBER U.S. Patent Citations Data File (Hall, Jaffe, & Trajtenberg, 2001),

Harvard U.S. Patent Inventor Database (Lai, D'Amour, Yu, Sun, & Fleming, 2011), and the Kogan, Papanikolaou, Seru and Stoffman's (2011) dataset from its inception through November, 2014. I further supplemented this data using the hand-collected data from the USPTO website. Consistent with prior work, I used the application year in which firms applied for the patent rather than year in which the patent was granted (Ahuja, 2000). My last year of observation for the dependent variable is 2010. Since the patent grant lag is approximately 3-4 years, tracking the patents through 2014 reduces the right censoring bias for patents applied in 2010.

Next, I used the Office of Technology Assessment and Forecast concordance as of 2008, *otaf 283,* to convert my 4-digit SIC code to relevant pharmaceutical technology classes to identify pharmaceutical patents. Then, adjusting for name changes and M&As, I aggregated these patents at the parent firm level. Using the application year of patents entailed additional data collection effort when the original assignee firm merged or was acquired by another firm. A case in point is the US patent number 7,189,412. The patent was granted in 2007 to Aska Pharmaceutical but was applied for even before Aska existed. Aska was formed by the merger of Grelan Pharmaceutical and Teikoku Hormone in 2005 but the last application for this patent was filed in 2004. In this case, I tracked other prior patents (patent number JPH09227364A) of Masaru Okamoto, the inventor of the US patent number 7,189,412, and identified the original assignee to be Grelan Pharmaceutical for the year 2004. Thus, in these cases, I tracked the prior patent applications of the inventors of the granted patents to find their original employers (assignees) in the patent application year and, thus, assigned the granted patent to the firm

which actually applied for that patent.

I matched this patent dataset with the data on 208 focal firms with 1,379 firm-year observations. First, I matched the two datasets using firms' CUSIP (Committee on Uniform Securities Identification Procedures) numbers. I was careful not to 'blindly' match the CUSIP numbers. The reason is that CUSIP number changes even when firms change their names. For example, Liposome Technology (CUSIP number 536311) changed its name to Sequus Pharmaceuticals (CUSIP number 817471) in 1995. As a result, a single firm might appear as two separate firms in the datasets if I ignore the name changes, thus both overstating the number of firms in my sample and making the match less likely if one of the firms were missing in one of the databases. In addition, alliance datasets such as the SDC use historical CUSIP, i.e., the CUSIP assigned to firms on the date the alliance was reported whereas patent datasets such as NBER use the updated GVKEY or CUSIP at the time when the dataset was merged with the COMPUSTAT database. To alleviate these issues, I created my own database of all the name changes that the firms in my sample underwent. Then, I used the CUSIP history (historical CUSIP and updated CUSIP) from the WRDS CRSP database to assign the appropriate CUSIP to firms before matching.

Second, I used the exact name matching to identify the patents of the remaining firms in the alliance-network dataset. Third, I used Hall's (2008) name-matching algorithm, with some modifications to enhance its workability, to match the firms left after the previous step. Fourth, I manually matched the remaining unmatched firms in the alliance-network dataset. I standardized and sorted all the firms in the patent dataset in

alphabetical order to make the matching from visual inspection feasible. Finally, I manually searched for the remaining unmatched firms in the alliance-network dataset using the google patent search engine (https://patents.google.com/) to confirm that the unmatched firms did not patent at all.

I further triangulated the matched data by comparing the adjustments for M&As and reorganizations in the patent and network databases. My final usable sample consists of an unbalanced panel of 198 U.S. pharmaceutical firms with 1,236 firm-year observations. An unbalanced panel is close to empirical reality and "is preferable" because it avoids survivorship bias (Baum, 2006).

**Dependent Variable**

***Citation-weighted patent count sans self-citations.*** I measure the focal firm *i*'s innovation output for year *t*, as the citation-weighted patent count of granted patents *p* applied for in a five-year window (*t* + 1 to *t* + 5) as: $\sum_{n=1}^{p}(1 + Citation_n)$, where $Citation_n$ is the total number of citations, net of self-citations, for the $n^{th}$ patent (Trajtenberg, 1990). Most firms apply for patents within five years of conducting R&D (Jaffe et al., 1993). Citation-weighted patents have been used extensively in innovation studies, with time frames ranging from one to five years (cf. Sampson, 2007; Vasudeva, Zaheer, & Hernandez, 2012; Kotha, Zheng, & George, 2011; Funk, 2014). Citation-weighted patent counts are more informative than simple patent counts in capturing the value of underlying innovations, or the value of R&D outputs (Trajtenberg, 1990).

Though patent-based measures correlate highly with other measures of innovation performance such as new products (Comanor & Scherer, 1969) and market value (Hall et

al., 2005), they are not without limitations. Specifically, they do not represent innovations without paper trails such as those based on trade secrets. However, any alternative data collection effort that matches the volume and depth of information provided by patents would be an extreme challenge. Further, some have argued that though citation-weighted patent measures are better than simple patent counts in capturing the differences in values of individual patents, they are still susceptible to interindustry variations in patenting propensity. My focus on a single industry, pharmaceuticals, in which patenting is commonplace, mitigates such issues because patenting propensity is more likely to be stable within a single industry (Ahuja, 2000). In addition, my firm fixed-effects specification controls for the time-invariant unobserved heterogeneity in patenting.

**Independent Variables**

***Stability***. Stability of the ego network captures the extent to which the focal firm's ego network remains unchanged from one time period to the next. I measure stability as the percentage composition of the focal firm's partners in its ego network that stayed the same. I operationalize firm-level stability in two steps. First, I calculate network churn as the percentage of the focal firm's alliance partners that change (are added or lost) from one year to the next (Burt & Merluzzi, 2016). I calculate the ratio for year $t_2$ with the total number of a) new ties that the focal firm formed between year $t_1$ and year $t_2$; and b) old ties that the focal firm dissolved between year $t_1$ and year $t_2$ as the numerator (Sasovova et al., 2010), and the total number of unique ties the focal firm had during the period as the denominator (Burt & Merluzzi, 2016). Figure 1 illustrates the calculation of churn for Amgen in 2001. From 2000 to 2001, Amgen dissolved two ties (Arris and Techne) and

initiated one new tie (Perkin-Elmer), resulting in a total change of three. During this period, Amgen had ten unique ties (Arris, NPS, Chugai, Indevus, Techne, Yamanouchi, Roche, Perkin-Elmer, Sumitomo, and Regeneron). Thus, 30 percent of Amgen's ties changed in 2001; therefore the churn rate of Amgen is 0.3.

Second, I measure the network stability at the focal-firm level using the transformation $Stability_{it}$=1- $Churn_{it}$. In other words, the focal firm's ego-network stability in year $t_2$ is the percentage of ties that stay the same from year $t_1$ to year $t_2$. For Amgen for 2001, the stability is thus 1 - 0.3 or 0.70. When the focal firm enters the sample for the first time, I assign a stability score of *1*, in other words, assume the firm experiences zero churn in that year.

**Control Variables**

***Structural holes***. Structural holes capture the lack of constraint faced by the focal firm as regards its relationship with the partner firms in its ego network. I measure structural holes in three stages. First, I compute the dyadic constraint using Burt's (1992) formula $c_{iqt}=\left(p_{iqt}+\sum p_{ikt}p_{kqt}\right)^2$, $k \neq i, q$, where $p_{iqt}$ measures the proportion of the focal firm *i*'s involvement with the alter firm *q* in year *t*. The term $\sum p_{ikt}p_{kqt}$ represents the aggregate indirect tie strength between firms *i* and *q* via firm *k* in year *t.* A higher value means that not only the focal firm has invested a large amount of time on the alter firm but also that indirect ties impose constraint on the focal firm to negotiate better terms. Second, I calculate the aggregate constraint faced by the focal firm *i* in year *t* using $C_{it}=\sum_q c_{iqt}$. Though in practice it varies from *0* to *1*, the measure can exceed *1* (Borgatti,

2014) when *q* is not *i*'s only contact (Burt, 1992: 55) Third, I measure access to structural holes using the Zaheer and Bell's (2005) transformation $Structural\ holes_{it}$=1- $C_{it}$. A high score indicates exclusive access to alter firms and the measure differentiates between closed and open triads in the focal firm's ego network (Tatarynowicz, Sytch, & Gulati, 2016). I prefer this measure to other efficiency-based measures because it captures the focal firm's dependence in relationships and better reflects the ability of the focal firm to negotiate and exploit entrepreneurial opportunities (Burt, 1992).

***Geographic concentration (focal firm).*** The underlying latent variable I attempt to capture is the focal firm's geographic organization of activities for innovation. I use the Herfindahl-Hirschman Index (HHI) of the focal firm's inventive activities using inventor location data for each year from the focal firm's patents. I calculate this measure as $\sum_i in_i^2$, where *i* indexes the countries in which the focal firm's inventors are present and $in_i$ is the fraction of the focal firm's patents in country *i*. An index value of *1* would indicate that the research is concentrated in a single country. Firms with missing inventor locations were assigned a score of *1*, assuming no international presence.

I employed a robustness test, and find consistent results, with an alternative measure of the firm's geographic configuration that accounts for the organization in different countries of the focal firm's subsidiaries that formed alliances during my sampling period. For year *t*, using the countries of the focal firm's subsidiaries that participated in alliances, I calculate the geographic concentration as $\sum_i c_i^2$, where *i* indexes the countries in which the focal firm's subsidiaries are present and $c_i$ is the

fraction of the focal firm's alliances in country *i*. Like for its inventors, an index value of *1* indicates that all of the firm's subsidiaries with alliances are present in one country.

***Direct ties.*** The innovation benefits of knowledge exchange and scale provided by the focal firm's direct partners might be correlated with the advantages from spanning structural holes (Ahuja, 2000).I control for Freeman's (1978) degree centrality of the focal firm by calculating the number of dyadic ties between the focal firm and its alter firms in a network at time *t*.

***Indirect ties.*** I counted the number of firms to which the focal firm was indirectly connected in the whole network for year *t* to capture knowledge sharing via informal channels in the network (Ahuja, 2000).

***Technological opportunity.*** This measure controls for the fact that the focal firm's patenting might be affected by the opportunities it foresees in different technological domains. For year *t*, I constructed this variable as the sum of the total number of patents by all firms in that year in the technology classes in which the focal firm patented, weighted by the proportion of the focal firm's patents in each class (Ahuja, 2000). The technological opportunity variable is coded zero if the focal firm does not patent in that year.

***Technological base (log).*** I measure the focal firm's technological base, a proxy for the absorptive capacity and aggregate R&D, as the logged cumulative patent counts until year *t,* with zero replaced by a very small number (0.0001) before transformation (Funk, 2014). The focal firm with no patents till year *t* is coded *0*. I use a discounted stock model in which past patents are valued less than recent ones calculated as

$\sum_{\alpha=1}^{t}(1 - discount)^{t-\alpha} PS_{i\alpha}$ where *PS* is the number of patents at time $\alpha$ and the annual discount rate is 15% (Hall et al., 2005).

***Technological diversity (focal firm).*** In order to account for the technological scope of the focal firm based on its innovations until year *t*, I calculate the Blau Index of diversity (Blau, 1977) as $1 - \sum_i pat_i^2$, where *i* indexes the patent classes in which the focal firm has patented thus far and $pat_i$ is the proportion of the focal firm's patents in patent class *i* (Jiang, Tao, & Santoro, 2010; Vasudeva et al., 2012). An index value of *1* indicates perfect heterogeneity whereas *0* denotes exact homogeneity. The diversity measure is assigned a value of zero if the focal firm did not patent until year *t*.

***Technological distance (cosine).*** To measure technological similarity between the focal firm and its partners for each firm-year *t*, I construct a *k*-dimensional vector *l* containing the cumulative distribution of a firm's patenting across different patent classes until year *t* such that each element of the vector is equal to the fraction of the firm's patents in a class *k*. Next, I calculate the cosine angular distance (Jaffe, 1986) between a firm *i* and its partner *j* using $cosine_{ijt} = l_{it}l_{jt}' / \sqrt{(l_{it}l_{it}')(l_{jt}l_{jt}')}$. This measure ranges from *0* to *1*, where *1* represents complete similarity. Next, I average the cosine distance between the focal firm and its partners to calculate the aggregate measure. When the focal firm patents but none of its alter firms do, I assume a distance of zero.

***Industry similarity.*** To capture the effect of market-resource overlap, I measure the proportion of the focal firm's alliance partners that operate in the same four-digit SIC codes as the focal firm (Polidoro, Ahuja, & Mitchell, 2011). Lavie (2007) finds that when

alliance partners and the focal firm belong to the same industry, alliance partners' increased bargaining power places limits on the focal firm's knowledge appropriation capacity, affecting innovation.

***Partners' innovation value*.** The focal firm might gain more from partners that have more valuable patents than from those who have less worthy patents. I account for these differences in the technological importance of partners using the percentage of citations received by partners' patent out of total pharmaceutical patent citations up to year *t* (Vasudeva et al., 2012).

***Technological diversity (alliance partners)*.** The focal firm's alliance partners' willingness to share knowledge for innovation might depend on whether or not the partners are working in the same technological space. Similar to the technological diversity of the focal firm, I control for this using the Blau Index of partners' patent diversity (Blau, 1977) as $1-\sum_i partnerpat_i^2$, where *i* indexes the patent classes in which the partner firms have patented thus far and $partnerpat_i$ is the proportion of the partner firms' patents in patent class *i* (Vasudeva et al., 2012). An index value of *1* indicates perfect heterogeneity whereas *0* exact homogeneity. The diversity measure is assigned zero if none of the focal firm's partners patent until year *t*.

***Equity alliance (% of total alliance)*.** For year *t*, I control for the differences in firms' incentives based on the proportion of alliances with equity transfer, cross equity transfer, or joint venture in the alliance network (Lavie & Miller, 2008).

***Cross-border participants (% of total alliance)*.** For year *t*, I calculate the

proportion of the focal firm's international partners to control for the knowledge diversity imparted by foreign firms (Phelps, 2010).

***Knowledge alliances (% of total).*** I control for the proportion of R&D, cross-technology, or cross-licensing alliances that might affect patenting more directly relative to the other types of alliances in each alliance network (Schilling & Phelps, 2007).

***Cumulative alliance experience (focal firm).*** I capture the focal firm's differences in the management of alliances using the total number of alliances up to year *t* (Anand & Khanna, 2000).

***Average age of alliances.*** The focal firm's alliance duration might affect both stability and innovation performance. I control for this using the mean age of the focal firm's alliances in year *t* (Soda et al., 2004).

***Acquirer dummy.*** I code the *Acquirer dummy* variable *1* in year *t* when the focal firm acquired for the first time any other firm from my sample during the period the focal firm was present in my sample to control for firm entry by acquisition.

***Mergers and acquisitions stock (log).*** I measure the firm's propensity to innovate because of M&As by using its logged cumulative stock of M&As till time *t*, with zero substituted for a very small number (0.0001).

***Status (Bonacich centrality).*** Scholars have shown status to affect firm performance (Podolny, 1993; Ertug & Castellucci, 2013). I capture status as normalized Bonacich power centrality (Bonacich, 1987).

**Model estimation**

My dependent variable, *Citation-weighted patent count sans self-citations*, is limited (nonnegative) and takes only discrete (integer) values (Maddala, 1983). In such cases, estimation by the linear regression model will generally have heteroscedastic and non-normal idiosyncratic errors (Manning, 1998; Manning & Mullahy, 2001). Also, the predicted conditional mean values can be negative. I cannot log transform the dependent variable because 15% of the count data is zero (Wooldridge, 2010). A brute-force log transformation (adding a small positive quantity $\Delta$ to my dependent variable) yields $E[\ln(\Delta + y \mid \boldsymbol{x})]$ which cannot be retransformed to get my regression of interest $E(y \mid \boldsymbol{x})$ (O'hara & Kotze, 2010; Wooldridge, 2010). Also, it yields biased parameter estimates (King, 1988). Any model from the linear exponential family such as the Poisson or the negative binomial is a better fit here (Allison, 2009). Consequently, I use the Poisson fixed effects unconditional quasi-maximum likelihood estimator in which the conditional mean of my model ($y_{it} = \alpha_i e^{\boldsymbol{x}'_{it}\beta} + \epsilon_{it}$) takes the exponential form

$$E\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i\right] = \alpha_i e^{\boldsymbol{x}'_{it}\beta} = e^{(ln\alpha_i + \boldsymbol{x}'_{it}\beta)},\ t = 1, 2, \ldots, T,\ i = 1, 2, \ldots, N, \quad (1)$$

where $y_{it}$ is the citation-weighted patent count net of self-citations for the pharmaceutical firm *i* at time *t*, $\boldsymbol{x_{it}}$ include the independent variable, controls, and time effects, $\beta$ are estimated regression coefficients, $\alpha_i$ are firm-specific unobserved time-constant effects, and $\epsilon_{it}$ are idiosyncratic errors (shocks) (Cameron & Trivedi, 2013). The fixed-effects estimator controls for the unobserved differences in the focal firm's predisposition to patent. The firm-effects $\alpha_i$ in this case are allowed to be correlated with the predictor

variables $\boldsymbol{x_{it}}$. The estimation assumes strict exogeneity in that any of the past, present, and future shocks (idiosyncratic errors) $\epsilon_{it}$ are uncorrelated with any of the explanatory variables $\boldsymbol{x_{it}}$ conditional on the unobserved effects $\alpha_i$ (Wooldridge, 2010). In other words, $E[y_{it} \mid \boldsymbol{x}_{i1}, \boldsymbol{x}_{i2}, \ldots, \boldsymbol{x}_{iT}, \alpha_i] = E[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]$ (2)

I choose the Poisson fixed effects unconditional quasi (pseudo)-maximum likelihood estimator for six reasons. First, the estimator allows for the consistent estimation of $\beta$ without any incidental parameters problem (Lancaster, 2002). Second, the marginal effects are identified (estimable) in this case in contrast to the Poisson conditional maximum likelihood (CMLE) and the generalized method of moments (GMM) estimators (Greene, 2002) because the first-order partial derivative of the conditional mean with respect to any explanatory variable ($\frac{\partial \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]}{\partial \boldsymbol{x}_{itj}}$) will always contain the multiplicative term $\alpha_i e^{\boldsymbol{x}_{it}'\beta}$ and these estimators eliminate the fixed effects $\alpha_i$. The conditional maximum likelihood estimators estimate $\beta$ by partialling out the firm-specific latent effects using the sufficient statistics $\sum_t y_{it}$ (Blundell, Griffith, & Van Reenan, 1999); and the generalized-method-of-moments (GMM) estimators estimate $\beta$ by conditioning out the fixed effects using a quasi-differencing term $\left(\frac{\lambda_{it}\bar{y}_i}{\bar{\lambda}_i}\right)$.

Third, "access to longitudinal data can control for heterogeneity through the individual-specific effect $\alpha_i$, so the efficiency gains in going beyond Poisson models may not be as great as in the cross-section case" (Cameron & Trivedi, 2013: 347; Hsiao, 2014). Fourth, the quasi-maximum likelihood estimation estimates "sandwich" cluster-

robust variance-covariance matrix that accounts for any intra-firm correlation and overdispersion (Wooldridge, 1999). Fifth, the Poisson fixed-effects estimator is robust to distributional misspecification (overdispersion or underdispersion) in its estimation of $\beta$ as long as the conditional mean specification in Equation (1) holds (Gourieroux, Monfort, & Trognon, 1984; Wooldridge, 2010). Sixth, the Poisson fixed-effects estimation applies equally well to any positive-skewed continuous variable whose domain is nonnegative (Wooldridge, 2010).

In contrast, the negative binomial maximum likelihood estimators, both NB1, in which the exponent of mean in the variance equation of count variable is *1*, and NB2, in which the exponent of mean is *2*, are very sensitive to variance misspecification, making the estimation inconsistent when variance is incorrectly specified (Cameron & Trivedi, 2010, 1986). Furthermore, in the case of unconditional maximum likelihood fixed-effects estimation, the negative binomial estimators do not provide consistent estimates of $\beta$ because of the incidental parameters problem (Greene, 2007; Hilbe, 2011). Jointly estimating *N* different incidental parameters $\alpha$ and *K* different $\beta$ parameters makes the number of estimated parameters to be estimated go to infinity, thus diluting the efficacy of a large sample (*NT*) with fixed *T* and large *N* and making the estimation of $\beta$ inconsistent (Wooldridge, 2010). Moreover, negative binomial fixed-effects estimators are restrictive in that "parametric model results are most easily obtained for the Poisson" whereas the iterative algorithm in the negative binomial case might not converge (Cameron & Trivedi, 2013: 347, 2010; Winkelmann, 2008). Moreover, some estimation

methods such as conditional maximum likelihood apply only to the NB1 model and not the NB2.

Thus, the Poisson unconditional fixed effects quasi-maximum likelihood estimator is appropriate for my empirical context because I can identify both consistent $\beta$ and the marginal effects. One caveat on using the quasi-maximum likelihood method is that we cannot predict the probabilities of counts because the actual conditional density of the count variable might be different (Wooldridge, 1997a). However, my main focus is on the expected value of the count not the probability. I also used several alternative model specifications as robustness tests (reported below).

There could still be some concern that though the model consistently estimates $\beta$ parameters, $\alpha_i$ might be inconsistent because of their dependence on group size ($T$). To the best of my knowledge none of the studies have looked at the impact of possibly inconsistent incidental parameters $\alpha_i$ on the marginal effects of the explanatory variables $\boldsymbol{x}_{it}$ whose estimates are consistent. I surmise that it is a lesser evil for two reasons. First, even when both $\alpha_i$ and $\beta$ are inconsistently estimated and the incidental parameters problem are present (not in my case), the marginal effects "have reasonable properties" (Wooldridge, 2010: 618; Fernàndez-Val, 2009). In binary choice models, Greene (2004a: 110; words [in brackets] added) finds that "the marginal effect [at the mean] is closer to the true value than the coefficient estimator is to its population counterpart." Also, the biases are much smaller than those in coefficients (Greene, 2004b), with the bias in the marginal effect at the mean being possibly smaller than the average of individual marginal effects (Greene, 2004a). Second, the bias might not be serious for $T \geq 5$

(Wooldridge, 2010). Greene (2004a) does not find the bias to be as severe as that described in Hsiao (2014) even for $T = 2$.

**Results**

Table 1 provides the descriptive statistics and the Pearson's (bivariate) correlation matrix for my variables. Though some variables exhibit moderate-to-high correlation, this is not an issue because the variance inflation factor (VIF) for the overall model does not exceed 10 (Kleinbaum, Kupper, & Muller, 1988), with the mean VIF being 7.72. Even though I use a nonlinear regression model, I calculate the VIF using a linear regression because multicollinearity is independent of the nature of the dependent variable (count or otherwise) and is determined solely by the right-hand side predictor variables. An interesting side-note is that how measures of multicollinearity (e.g., VIFs) relate to the regression coefficients in nonlinear models remains an open question (for an exception, see Bonate [1999]) and the VIF might not tell the complete story.

I mean-centered *Structural holes, Geographic concentration (focal firm)* and *Stability* to eliminate nonessential multicollinearity and to "increase the interpretability of regression coefficients" because of the presence of interaction term in the full model (Hoffman & Gavin, 1998; Afshartous & Preston, 2011: 2; Aiken & West, 1991). As shown in Table 1, my stability measure is negatively, though not significantly, correlated with size-related measures such as direct ties, the focal firm's technological base, and indirect ties. One could argue that large networks are more prone to change just by random chance, as explained by the negative correlation. The ego-network stability is positively correlated with technological similarity between focal firms and alters ($r$ =

0.08; $p < 0.01$), focal firms' cumulative alliance experience ($r = 0.06$; $p < 0.05$), and the average age of alliances in focal firms' ego network ($r = 0.30$; $p < 0.01$). Some of these correlations can be explained by noting that firms with greater alliance experience might be more successful in retaining alliance partners. Increased alliance age might translate into enhanced trust and repeated partnerships, thus enhancing their stability. Consistent with extant theorizing that structural holes are fragile, stability is negatively associated with structural holes ($r = -0.07$; $p < 0.05$). The geographic concentration of inventive activities, one of my moderators, is negatively correlated with size-based measures, namely, direct ties ($r = -0.47$; $p < 0.01$) and technological base ($r = -0.29$; $p < 0.01$), suggesting that large firms are less likely to be geographically concentrated. Similarly, firms are less likely to find alliance partners with high innovation value when the focal firms are geographically concentrated ($r = -0.36$; $p < 0.01$).

Table 2 presents results of the regression analysis using the Poisson fixed effects unconditional maximum likelihood estimator. Model 1 in Table 2 is a control variables only baseline model. *Structural holes*, a moderator variable, *Geographic concentration*, another moderator variable, and *Stability*, my main variable in the study, enter in Model 2. I add the interaction between *Stability* and *Structural holes* in Model 3 and the interaction between *Stability* and *Geographic concentration* in Model 4. Model 5 is my fully specified model with all variables and interaction terms.

Consistent with much of the prior work, I find that innovation performance increases with access to structural holes. The coefficients of *Structural holes* in Models 2, 3, 4, and 5 are positive and significant ($p < 0.05$). I plotted in the top left corner of Figure

2 the predicted values of the conditional mean counts against *Structural holes* using the regression estimates from Model 5, holding the other variables constant at their respective sample mean values. *Structural holes* has a positive and increasing impact on the conditional mean across the range of its observed values.

In nonlinear estimators, the marginal effects of changing predictors differ from those calculated directly using the regression-coefficient estimates (Greene, 2007). Thus, I also investigate the marginal effect of *Structural holes* on my dependent variable, keeping all the other variables at their sample mean values (Long, 1997). I calculate the marginal effect by taking the partial derivative of Equation (1) with respect to structural holes in Model 5 (Cameron & Trivedi, 2013; Shaver, 2007).

$$Marginal\ Effect_{Structural\ holes} =$$

$$\frac{\partial \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]}{\partial x_{itStructural\ holes}} = \alpha_i e^{\boldsymbol{x}_{it}'\beta}(\beta_{Structural\ holes} + \beta_{Stability\ X\ Structural\ holes}\ Stability) \quad (3)$$

The marginal effect of *Structural holes* at the sample mean of all variables is 12.43 citation-weighted patent counts net of self-citations ($p < 0.05$). In other words, 12.43 is the instantaneous rate of change or the marginal change in the predicted conditional expected value of *Citation-weighted patents sans self-citations* with respect to *Structural holes*, keeping other variables at their sample means (Long & Freese, 2014).

The range of *Structural holes* is approximately one, calling for changes in the variable that are of lesser magnitude than *1* for meaningful interpretation. Hence, I further investigated discrete effects of the variable using the finite-difference method (arbitrary changes in the variable), holding all other variables at their respective sample means

(Long, 1997).

$$\textit{Discrete Effect}_{\textit{Structural holes}} = \frac{\Delta \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]}{\Delta x_{\textit{itStructural holes}}} =$$

$$\mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{\textit{itS.holes}} = x_{\textit{itS. holes FINAL}}] - \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{\textit{itS.holes}} = x_{\textit{itS.holes INITIAL}}] \quad (4)$$

The discrete effect of an explanatory variable refers to the change in the expected count when the variable changes ($\nabla$=*final value* - *initial value*) from its initial value to the final value, when all other variables remain constant. The patent count increases by 4.63 as *Structural holes* increases from the 10$^{th}$ percentile to the 90$^{th}$ percentile ($\chi^2 = 5.27$; $p < 0.05$). These results are consistent with expectations about the beneficial effects of structural holes. I note that the formulae for the marginal and discrete effects in the case of *Geographic concentration* and *Stability* use a logic similar to that in Equations (3) and (4). Hence, I do not explicitly specify them in this essay to avoid repetition.

Models 2, 3, 4, and 5 show a significant, negative effect of *Geographic concentration* ($p < 0.05$). I graphed in the top right corner of Figure 2 the predicted values of the conditional mean of the dependent variable against *Geographic concentration* using the regression estimates from Model 5, with all other variables at their respective means. *Geographic concentration* negatively affects the conditional mean across the range of its observed values, though at a diminishing rate as *Geographic concentration* increases in value. The marginal effect of *Geographic concentration* at the sample mean of all variables is -10.84 citation-weighted patent count *sans* self-citations ($p < 0.05$). The expected count decreases by 2.27 as *Geographic concentration* increases from the 10$^{th}$

percentile to the 90$^{th}$ percentile ($\chi^2 = 5.65$; $p < 0.05$), thus suggesting that innovation performance decreases when firms' inventive activities are geographically concentrated.

Hypothesis 1 states that network stability negatively affects the focal firm's innovation performance. *Stability* has negative and significant ($p < 0.05$) coefficient estimates in Models, 2, 3, 4, and 5. I graphed in the bottom left corner of Figure 2 the expected count predictions against *Stability*. The bottom panel shows that *Stability* has a negative, but diminishing, and significant ($p < 0.05$) impact on the predicted mean counts. *Stability*, at the mean, reduces the conditional mean count of citation-weighted patents by 3.87 ($p < 0.01$). The mean count reduces by 1.96 when *Stability* increases from the 10$^{th}$ percentile to the 90$^{th}$ percentile ($\chi^2 = 8.49$; $p < 0.01$). These findings are consistent with H1.

Hypothesis 2 proposes a positive moderating effect of structural holes on the relationship between *Stability* and innovation performance. Equivalently, the effect of *Structural holes* on patent counts becomes more positive as the level of *Stability* increases and vice versa (Saunders, 1955). The coefficient of interaction between *Stability* and *Structural holes* is positive and significant ($p < 0.01$) in Model 3, and is positive and significant, though marginally, in Model 5 in Table 2 ($p < 0.10$). I plot this interaction in Panel A of Figure 3 to gain further insights. The graph shows that the negative effect of stability on the predicted patent counts is more detrimental to a focal firm with low levels of structural holes in its network than for a focal firm with high levels of structural holes.

We can interpret the interaction effect in two ways: one is to present the effect as

incidence-rate ratio (IRR) (multiplicative effects) and the other is to calculate marginal or discrete interaction effects (Buis, 2010). I discuss both to evaluate my hypothesis. Using the IRR, I find that as *Stability* increases by one unit when the focal firm spans no structural holes, the patent count reduces by a factor of 0.75 (or 25 percent reduction in patent counts). This effect of *Stability* on patent counts increases by a factor of 2.34 as *Structural holes* increases by one unit from zero to one. Hence, if the focal firm spans structural holes (or *Structural holes* = 1) then the effect of *Stability* is positive: 133.97 percent increase in patent counts with a unit increase in *Structural holes*. The effect is significant with 90 percent two-tailed confidence interval, marginally supporting H2. I note that the benefit of using the multiplicative interaction effects is that these effects control for differences in baseline IRRs in their own category: thus, these effects control for the baseline differences among firms with high and low *Stability* even when these firms do not span structural holes (or *Structural holes* = 0) (Buis, 2010).

As suggested by Ai and Norton (2003), I also calculate the marginal interaction effects on the predicted mean patent counts by taking the cross-partial derivative of Equation (1) with respect to *Structural holes* and *Stability* or by taking the partial derivative of Equation (3) with respect to *Stability*. The marginal interaction effect (Norton, Wang, & Ai, 2004; Shaver, 2007) is

$$\frac{\partial^2 \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]}{\partial x_{itStructural\ holes}\, \partial x_{itStability}} = \alpha_i e^{\boldsymbol{x}_{it}'\beta}[\beta_{Stability\ X\ S.holes} +$$

$$(\beta_{S.\ holes} + \beta_{Stability\ X\ S.\ holes}\ Stability)\ (\beta_{Stability} + \beta_{Stability\ X\ S.\ holes}\ Structural\ holes +$$

$$\beta_{Stability\ X\ Geog.\ concentration}\ Geographic\ concentration)] \qquad (5)$$

Substituting the coefficient estimates from Model 5 and holding all regressors at their sample mean values, the interaction effect of *Stability* and *Structural holes* on the expected patent count is 7.65. The effect is significant for one-tailed test at the 10% significance level, marginally confirming the veracity of my Hypothesis 2.

Next, in order to assess the effect of a discrete change in the level of *Structural holes* on the relationship between a discrete change in *Stability* and predicted mean count, I follow Zelner (2009) approach to calculate the interaction effect using the discrete double difference method. The discrete interaction effect is

$$\frac{\Delta^2 \mathrm{E}[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i]}{\Delta x_{itStability}\, \Delta x_{itS.\ holes}} = (\mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{itS.holes} = x_{itS.\ holes\ FINAL}, x_{itStability} = x_{itStability\ FINAL}\right]$$

$$- \mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{itS.holes} = x_{itS.holes\ INITIAL}, x_{itStability} = x_{itStability\ FINAL}\right])$$

$$- (\mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{itS.holes} = x_{itS.\ holes\ FINAL}, x_{itStability} = x_{itStability\ INITIAL}\right]$$

$$- \mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, x_{itS.holes} = x_{itS.holes\ INITIAL}, x_{itStability} = x_{itStability\ INITIAL}\right]) \qquad (6)$$

The discrete interaction effect on the expected value of patent count as *Structural holes* changes from low ($10^{th}$ percentile) to high ($90^{th}$ percentile) and *Stability* changes from low ($10^{th}$ percentile) to high ($10^{th}$ percentile) is 1.54. The effect is significant with 90 percent one-tailed confidence interval. Thus, I find marginal support for my second hypothesis.

I have faith in the validity of the use of one-tailed test for the marginal effects for H2 for two reasons. First, I formally hypothesize about the direction of the interaction effect and my hypothesis derives from theory. Second, interaction effects between continuous variables are, in general, difficult to detect at the 95 percent confidence level

(Morris, Sherman, & Mansfield, 1986; McClelland & Judd, 1993) because, among other things, the test lacks statistical power (Jaccard, Wan, & Turrisi, 1990). Given my constraints in increasing the sample size or in increasing the variance of the underlying variables, I chose to increase the significance level to increase the statistical power of the effect (Hoang & Rothaermel, 2005). The results largely support H2.

Hypothesis 3 states that *Geographic concentration* negatively moderates the relationship between *Stability* and innovation performance. Models 4 and 5 depict a negative and significant interaction effect of *Geographic concentration* ($p < 0.05$). I plot this interaction in Panel B of Figure 3. As can be seen, the effect of stability on the predicted value of citation-weighted counts net of self-citations is more negative as the focal firm's network is highly geographically concentrated, thus providing support for H3.

As regards multiplicative interaction effects, the effect of *Stability* on patent counts further decreases by a factor of 0.29 as *Geographic concentration* increases by one unit from zero to one. Hence, if the focal firm is geographically concentrated (or *Geographic concentration* = 1) then the effect of *Stability* is negative: 71.35 percent decrease in patent counts for each unit increase in *Geographic concentration*. The effect is significant with 95 percent two-tailed confidence interval, supporting H3.

To calculate marginal and discrete effects, I use Equations (5) and (6) with *Structural holes* replaced by *Geographic concentration* and vice versa, controlling for all other regressors at their sample means. Substituting the coefficient estimates from Model 5 and holding all regressors at their sample mean values, the interaction effect of *Stability*

and *Geographic concentration* on the expected patent count is -13.56. The effect is significant for two-tailed test at the 10% significance level, marginally confirming the veracity of my Hypothesis 3. The discrete interaction effect on the expected value of patent count as *Geographic concentration* changes from low ($10^{th}$ percentile) to high ($90^{th}$ percentile) and *Stability* changes from low ($10^{th}$ percentile) to high ($10^{th}$ percentile) is -1.48. The effect is significant with 90 percent two-tailed confidence interval. Thus, my third hypothesis is largely supported.

**Robustness Checks**

My results are robust to different measures of the dependent variable such as patents alone, and citations alone net of self-citations. Direct ties ($r = 0.69$; $p < 0.01$) and status ($r = 0.66$; $p < 0.01$) might be closely associated with structural holes (Borgatti, Everett, & Johnson, 2013). In addition, some other control variables are fairly highly correlated. *Direct ties* is highly correlated with status ($r = 0.80$; $p < 0.01$) and cumulative alliance experience ($r = 0.82$; $p < 0.01$), and status is correlated with partners' innovation value ($r = 0.72$; $p < 0.01$). I chose to retain them in my main model for four reasons. First, these controls derive from theory (Ahuja, 2000; Podolny, 1993; Vasudeva et al., 2012). Second, the overall VIF for the full model is less than ten. Third, my findings are robust with respect to excluding the direct ties, status, and partners' innovation value measure, either one at a time or jointly as shown in Appendix 3 (Models, 2, 3, 4, and 5) at the end of this chapter. Fourth, high correlation between control variables such as that between the direct ties and status in and of itself does not affect the "coefficients of the variables of interest… and the performance of the control variables as controls is not

impaired" (Allison, 2012:1) in that multicollinearity may not affect the joint significance of linear combination of these control variables (Kennedy, 2008).

In addition, firm size might be correlated with both innovation performance and my network measures. I use size-related measures such as technological base and direct ties in the main model. My results hold when I introduce an additional control for firm size using the logged number of employees (not shown). This measure exhibits high association with my technological base measure ($r = 0.74$; $p < 0.01$) indicating, as might be expected, that larger firms have larger technological bases. Next, in my sample, some firms do not patent. On the one hand, inclusion of such firms helps mitigate the self-selection on my dependent variable. On the other hand, such firms might be different from firms that patent in that such firms might be young with innovations underway. I categorize firms into innovators and imitators based on whether or not they have patents. However, my fixed-effects controls for such differences, and STATA omits this innovator variable. In addition, my results are stable to introducing R&D intensity to control for such differences in Appendix 3 (Model 6).

The Poisson conditional maximum likelihood estimator (not shown) provides consistent estimates as those in Model 5 of Table 2 (my main model), confirming the absence of incidental parameter bias. In Model 6 (Table 3) I use the Poisson-Gamma random effects estimator to alleviate the concern that the coefficients of some variables with relatively small within-firm standard deviation may limit their identification (Baum, 2006). The Poisson-Gamma random effects model effectively results in the negative binomial model (Greene, 2007). Coefficient estimates and their significance for my main

variables of interest are essentially unchanged in this model.

So far, my main results are based on the nonlinear fixed-effects model, which assumes that, conditional on the fixed effects $\alpha_i$, my count data $y_{it}$ do not exhibit correlation over time. However, firms' current patent counts might be influenced by past realizations of successful patents, inducing autocorrelation in the count response even after controlling for latent firm heterogeneity. In the presence of dynamic feedback from the dependent variable (state dependence), the strict exogeneity assumption in Equation (2) is violated, making my Poisson fixed effect estimator inconsistent. The conditional mean in this case depends on both the current and past $\boldsymbol{x}_{it}$ values and lagged count values. In this case, though the GMM estimators using, among others, Chamberlain (1992) or Wooldridge transformation (1997b), can replicate the fixed effects nonlinear model with dynamic feedback under weak exogeneity, the marginal effects are not identified because of the elimination of $\alpha_i$. Also, the algorithm for the GMM estimation might not converge. Hence, I use the conditionally correlated Poisson-Gamma random effects dynamic model (CCRE model) in Model 7 (Table 3) to account for dynamic feedback using the Wooldridge (2005) and Mundlak (1978) corrections (Cameron & Trivedi, 2013).

The fixed-effects model, as discussed earlier, allows the firm-specific time-invariant latent heterogeneity $\alpha_i$ to correlate with the time-varying observed heterogeneity (represented by predictor variables) $\boldsymbol{x}_{it}$ but does not put any restriction on its distribution, permitting arbitrary correlation. In contrast, the Poisson random-effects model considers the firm effect $\alpha_i$ independent and identically distributed (iid) (i.e., not correlated with

regressors) drawn from the gamma (conjugate to the Poisson density) distribution (shape = ω, scale = ω) with mean 1 and variance 1 / ω. In other words, we specify a distribution for the random-effects model unlike that in the case of the fixed-effects model. The CCRE models in my case explicitly model the correlation between $\alpha_i$ and $\boldsymbol{x}_{it}$, restricting the distribution of $\alpha_i$ and making it conditional on the predictors. In the nonlinear case, the Poisson fixed-effects estimators and CCRE estimators yield similar estimates of coefficients and standard errors (Cameron & Trivedi, 2013), and the marginal effects are identified (Wooldridge, 2010).

Conditionally correlated Poisson-gamma random effects dynamic estimators model the unobserved variable $\alpha_i$ as two (multiplicative) components, the correlated unobserved heterogeneity ($e^{(\theta_0 y_{iINITIAL} + \bar{\boldsymbol{x}}_i'\gamma)}$) and random unobserved heterogeneity($e^{\varepsilon_i}$), which is iid gamma distributed. Equivalently, $\varepsilon_i$ follow log-gamma distribution. The sufficient statistics to proxy for the correlation in the CCRE model consists of two components, viz., the statistic ($y_{iINITIAL}$ = *Citation-weighted patent counts sans self-citations* of a firm *i* at time zero before its entry into the sample ~ initial condition) that reflects correlation between $\alpha_i$ and the dynamic regressor $y_{it-1}$ (Wooldridge, 2005); and the statistic ($\bar{\boldsymbol{x}}_i$ = within-firm average of each time-varying regressors) that controls for the correlation between $\alpha_i$ and other time varying regressors $\boldsymbol{x}_{it}$, excluding the time dummies (Mundlak, 1978 ). I note that in CCRE models the sufficient statistics enter as regressors to proxy for $\alpha_i$, not to eliminate $\alpha_i$. My estimator is $\mathrm{E}\left[y_{it} \mid \boldsymbol{X}_{i(t)}, \boldsymbol{Y}_{i(t-1)}, \alpha_i\right] =$

$$\alpha_i e^{(\boldsymbol{x}_{it}'\beta + \delta y_{it-1})} = e^{(\theta_0 y_{iINITIAL} + \bar{\boldsymbol{x}}_i'\gamma)}\, e^{\varepsilon_i}\, e^{(\boldsymbol{x}_{it}'\beta + \delta y_{it-1})} = e^{(\boldsymbol{x}_{it}'\beta + \delta y_{it-1} + \theta_0 y_{iINITIAL} + \bar{\boldsymbol{x}}_i'\gamma + \varepsilon_i)} \quad (7)$$

where $\boldsymbol{X}_{i(t)} = (\boldsymbol{x}_{i1},\boldsymbol{x}_{i2},\ldots,\boldsymbol{x}_{it})$, $\boldsymbol{Y}_{i(t)} = \left(y_{i1},y_{i2},\ldots,y_{it-1}\right)$, and is estimated using the Poisson-gamma random effects estimator (Cameron & Trivedi, 2013). I also note that the covariates here are weakly exogenous (predetermined). The estimator exhibits exponential feedback. Though Blundell, Griffith, and Windmeijer (2002) call for linear feedback to overcome the explosive nature ($\delta y_{it-1} \geq 0$ if $\delta > 0$) of the exponential estimator, explosiveness is a nonissue in short panels and "the relative ease of interpretation favors the" exponential feedback model (Cameron & Trivedi, 2013: 371).

I suppress, for brevity, the coefficient estimates of initial conditions and other sufficient statistics (available upon request). In Model 7 (Table 3), my lagged dependent variable, *Citation-weighted patent count sans self-citations*$_{-1}$ is significant at the 1% level. Its coefficient estimate is very close to zero (a little greater), making the model very slightly explosive. Though the coefficient for *Geographic concentration* is not significant, it is in the right direction, i.e., negative as hypothesized. *Structural holes* ($p < 0.05$), *Stability* ($p < 0.01$), the interaction between *Structural holes* and *Stability* ($p < 0.05$), and the interaction term between *Geographic concentration* and *Stability* ($p < 0.10$) have the same signs as those in my main Model 5 in Table 2. Overall, the results are similar to those in Table 2 and confirm hypotheses support from the main analyses.

Next, I delve into another source of autocorrelation in $y_{it}$, over and above that controlling for $\alpha_i$. In Model 8 (Table 3) I test for the possible endogeneity of *Structural holes* manifested in the autocorrelation of $\varepsilon_{it}$ in that firms with more patent counts may be likelier to span more structural holes. The use of inverse Mills ratio derived from the

Heckman's (1979) method in any fixed-effects nonlinear estimator might result in inconsistent estimates (Terza, 1998). Hence, I use a two-part approach suited for nonlinear models known as the Control Function approach for the Poisson fixed-effects estimator based on the recursive system (Wooldridge, 2015).

$$\mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, S.holes_{it}, u_{it1}\right] = \alpha_{i1} \mathrm{e}^{(\boldsymbol{x}_{it}'\beta_1 + \kappa_1 S.holes_{it} + C_1 Stability \times S.holes_{it} + u_{it1})} \quad (8.1)$$

$$S.holes_{it} = \boldsymbol{z}_{1it}'\boldsymbol{\beta}_2 + \boldsymbol{z}_{2it}'\xi_2 + \alpha_{i2} + \varepsilon_{it2} \text{ (reduced-form equation } \textit{Structural holes}) \quad (8.2)$$

$$u_{it1} = \rho\varepsilon_{it2} + \varepsilon_{it} \quad \text{(Wooldridge, 1997a)} \quad (8.3)$$

where $\boldsymbol{z}_{1it}$ contains all the exogenous variables from Equation (8.1), i.e., $\boldsymbol{x}_{it}$ (controls, time dummies, and *Stability*) and $\boldsymbol{z}_{2it}$ excluded exogenous variables or instruments.

The instrument should capture the variation in *Structural holes* but should not influence patent counts directly. I use uncertainty experienced by the focal firm in innovation as an excluded instrument for *Structural holes* to capture the firm's willingness to engage in an alliance (Pfeffer & Nowak, 1976) and to span structural holes. Uncertainty faced by the focal firm negatively affects *Structural holes* (Martin, Gözübüyük, & Becerra, 2015). When faced with firm-specific uncertainty, the focal firm would reduce the search costs associated with new potential alter firms and the risk of opportunistic behavior by members of its ego network. Consequently, it would engage in fewer structural holes (Gulati, 1995a). I measure uncertainty by the standard deviation of the rolling five-year window of patent counts of the focal firm until time *t* (Martin et al., 2015). I created an additional instrument by multiplying *Stability* with this uncertainty measure (Angrist & Pischke, 2009). In the first stage (results available upon request), I

use a linear fixed-effects panel data estimator in Equation (8.2) to predict the residuals ($\widehat{\ddot{\varepsilon}_{it2}} = \ddot{S.holes}_{i\,t} - \ddot{\mathbf{z}}'_{1it}\hat{\boldsymbol{\beta}}_2 - \ddot{\mathbf{z}}'_{2it}\hat{\xi}_2$, where ¨ symbolizes firm-specific deviations from the time-averaged values of the respective variables). The two instruments are jointly significant ($F = 4.48$, $p < 0.05$).

Although my test statistic misses the Stock, Wright, and Yogo (2002) criterion value of 10, I believe it is not a serious issue for three reasons. First, it is difficult to find strong significance when we add interactions in general. Second, we "can't always determine instrument relevance using a mechanical rule, such as "f > 10." In some cases, a low F may not be fatal" (Angrist & Pischke, 2009: 215). Angrist and Pischke (2009) find the value of 4.91 to be relevant too in their example. Third, I already explicitly control for the principal determinants of alliance formation such as alliance experience, status, and direct ties.

In the second stage, I estimate the Poisson fixed-effects model using the predicted residual from the first stage as a predictor in the mean function in Equation (8.1). $\mathrm{E}\left[y_{it} \mid \boldsymbol{x}_{it}, \alpha_i, S.holes_{it}, \widehat{\ddot{\varepsilon}_{it2}}\right] = \alpha_{i1}\mathrm{e}^{(\boldsymbol{x}'_{it}\beta_1 + \kappa_1 S.holes_{it} + C_1 Stability\ X\ S.holes_{it} + \rho\widehat{\ddot{\varepsilon}_{it2}})}$. Results show that there is not enough evidence to reject the null hypothesis of exogeneity of *Structural holes* ($\rho = 0$) using the robust Wald test, which is non-significant ($\chi^2 = 1.49$; $p = 0.22$). The results from my main analyses are supported, further validating the robustness of my conditional mean specification.

## SUMMARY

How does ego-network stability affect innovation performance? A long network research tradition has mostly argued that the configuration of network structures (e.g., structural holes) benefits firms' innovation performance. However, researchers appear to have overlooked a fundamental dimension of social structure, its stability. Consistent with much extant work, my baseline (but not hypothesized) findings indicate that a focal firm that spans structural holes reaps greater innovation benefits. However, in addition to the innovation benefits provided by network structure configuration *per se*, I empirically disentangle the negative innovation implications of ego-network stability and show how these effects are contingently influenced by network configurations, specifically, structural holes. Moreover, I demonstrate how the geographic concentration of the focal firm's inventive activities contingently accentuates the negative ego-network stability-performance relationship.

Specifically, I show that network stability has a detrimental effect on the focal firm's innovation performance. The effect, taken together with the mitigating influence of structural holes spanned by the focal firm, highlights the potentially opposing forces at play in assessing the value of ego networks. Bringing stability into the picture attenuates the knowledge benefits of ego networks because of knowledge retrieval difficulties, relational lock-in, and knowledge redundancy, thus reducing the heterogeneity in knowledge availability from the firm's network resources. However, compared to network closure, when the focal firm spans structural holes, it is able to limit the negative effects of stability.

The focal firm's geographic concentration, on the other hand, amplifies the negative impact of ego-network stability. The focal firm that lacks a multicountry operation is not able to exploit diversity benefits because both knowledge and labor are geographically constrained, with low mobility across geographic boundaries (Jaffe et al., 1993). In contrast to high concentration, low geographic concentration (high internationalization) allows the focal firm to access diverse knowledge from multiple countries, increasing the likelihood of recombination (Kogut & Zander, 1993).The focal firm with multicountry presence is able to learn from the different country-specific best practices for innovation, from the complexity involved in organizing, and from the ensuing employee diversity (Ghosal & Bartlett, 1988; Westney & Zaheer, 2008; Østergaard et al., 2011). In addition, multicountry location allows for the institutional arbitrage in which the focal firm benefits from the intercountry differences in knowledge-related input factors and output (Zhao, 2006).

**TABLE 1**

**Descriptive Statistics and Correlations**[a]

| Variable | Mean | S.D. Overall | S.D. Between | S.D. Within | Min. | Max. | Correlation 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | 17. | 18. | 19. | 20. | 21. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Citation-weighted patents *sans* self-citations | 322.54 | 872.07 | 432.72 | 552.01 | 0.00 | 7,267.00 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| 2. Direct ties | 4.37 | 4.51 | 2.60 | 2.48 | 2.00 | 36.00 | 0.38 | 1.00 | | | | | | | | | | | | | | | | | | | |
| 3. Indirect ties | 292.54 | 110.36 | 98.99 | 75.61 | 0.00 | 408.00 | -0.16 | 0.06 | 1.00 | | | | | | | | | | | | | | | | | | |
| 4. Technological opportunity | 837.69 | 605.17 | 495.73 | 452.46 | 0.00 | 2,712.50 | 0.01 | 0.18 | 0.38 | 1.00 | | | | | | | | | | | | | | | | | |
| 5. Technological base (log) | 1.75 | 3.98 | 4.31 | 1.63 | -9.21 | 7.06 | 0.30 | 0.36 | 0.10 | 0.52 | 1.00 | | | | | | | | | | | | | | | | |
| 6. Technological diversity (focal firm) | 0.66 | 0.23 | 0.25 | 0.06 | 0.00 | 0.90 | 0.19 | 0.23 | 0.14 | 0.26 | 0.71 | 1.00 | | | | | | | | | | | | | | | |
| 7. Technological distance (cosine) | 0.55 | 0.23 | 0.24 | 0.12 | 0.00 | 1.00 | -0.08 | 0.10 | 0.13 | 0.34 | 0.29 | 0.25 | 1.00 | | | | | | | | | | | | | | |
| 8. Industry similarity | 0.54 | 0.34 | 0.35 | 0.11 | 0.00 | 1.00 | 0.05 | 0.03 | -0.10 | -0.04 | -0.10 | -0.17 | 0.00 | 1.00 | | | | | | | | | | | | | |
| 9. Partners' innovation value | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 | 0.15 | 0.12 | 0.50 | 0.18 | 0.20 | 0.27 | 0.21 | 0.10 | -0.01 | 1.00 | | | | | | | | | | | | |
| 10. Technological diversity (alliance partners) | 0.81 | 0.14 | 0.15 | 0.05 | 0.00 | 0.90 | 0.06 | 0.13 | 0.36 | 0.20 | 0.31 | 0.31 | 0.06 | -0.08 | 0.27 | 1.00 | | | | | | | | | | | |
| 11. Equity alliance ( % of total alliance) | 0.11 | 0.20 | 0.20 | 0.08 | 0.00 | 1.00 | 0.07 | 0.02 | -0.25 | -0.09 | -0.09 | -0.13 | -0.05 | -0.06 | -0.09 | -0.27 | 1.00 | | | | | | | | | | |
| 12. Cross-border participants (% of total alliance) | 0.45 | 0.32 | 0.33 | 0.13 | 0.00 | 1.00 | -0.03 | -0.01 | -0.17 | -0.08 | -0.06 | -0.02 | 0.02 | -0.14 | -0.06 | 0.02 | -0.06 | 1.00 | | | | | | | | | |
| 13. Knowledge alliance (% of total alliance) | 0.63 | 0.32 | 0.33 | 0.13 | 0.00 | 1.00 | 0.00 | 0.01 | 0.28 | 0.17 | 0.16 | 0.18 | 0.03 | -0.12 | 0.14 | 0.30 | 0.01 | -0.05 | 1.00 | | | | | | | | |
| 14. Cumulative alliance experience (focal firm) | 31.27 | 53.06 | 25.03 | 37.45 | 2.00 | 458.00 | 0.13 | 0.82 | -0.02 | 0.13 | 0.32 | 0.22 | 0.17 | 0.02 | 0.44 | 0.12 | 0.03 | 0.01 | -0.00 | 1.00 | | | | | | | |
| 15. Average age of alliances | 4.94 | 2.95 | 2.17 | 2.25 | 1.00 | 15.00 | -0.16 | 0.13 | -0.07 | 0.06 | 0.16 | 0.18 | 0.37 | -0.04 | 0.11 | 0.11 | -0.03 | 0.13 | -0.05 | 0.41 | 1.00 | | | | | | |
| 16. Acquiror dummy | 0.24 | 0.43 | 0.35 | 0.21 | 0.00 | 1.00 | 0.17 | 0.48 | -0.03 | 0.13 | 0.24 | 0.14 | 0.16 | -0.01 | 0.28 | 0.08 | -0.00 | 0.05 | -0.00 | 0.44 | 0.34 | 1.00 | | | | | |
| 17. Mergers and acquisitions stock (log) | -3.85 | 5.23 | 4.67 | 2.43 | -9.21 | 3.97 | 0.25 | 0.42 | -0.01 | 0.10 | 0.23 | 0.17 | 0.09 | 0.08 | 0.19 | 0.06 | 0.01 | -0.00 | -0.01 | 0.40 | 0.26 | 0.58 | 1.00 | | | | |
| 18. Status (Bonacich centrality) | 0.96 | 0.88 | 0.63 | 0.47 | 0.00 | 5.89 | 0.31 | 0.80 | 0.11 | 0.19 | 0.38 | 0.29 | 0.13 | -0.03 | 0.72 | 0.28 | -0.04 | 0.04 | 0.14 | 0.67 | 0.18 | 0.42 | 0.35 | 1.00 | | | |
| 19. Structural holes | 0.63 | 0.17 | 0.15 | 0.08 | 0.00 | 0.97 | 0.33 | 0.69 | 0.09 | 0.24 | 0.42 | 0.28 | 0.18 | 0.09 | 0.50 | 0.20 | -0.11 | 0.02 | 0.06 | 0.52 | 0.17 | 0.43 | 0.43 | 0.66 | 1.00 | | |
| 20. Geographic concentration | 0.93 | 0.11 | 0.09 | 0.05 | 0.25 | 1.00 | -0.36 | -0.47 | 0.10 | -0.17 | -0.29 | -0.19 | -0.12 | 0.06 | -0.36 | 0.00 | -0.10 | -0.14 | 0.01 | -0.37 | -0.15 | -0.36 | -0.33 | -0.41 | -0.38 | 1.00 | |
| 21. Stability | 0.79 | 0.24 | 0.15 | 0.22 | 0.00 | 1.00 | -0.12 | -0.03 | -0.04 | -0.02 | -0.02 | -0.00 | 0.08 | -0.04 | -0.00 | -0.05 | 0.04 | 0.00 | -0.04 | 0.06 | 0.30 | -0.04 | -0.03 | -0.04 | -0.07 | 0.01 | 1.00 |

[a] The estimation sample is a 21-year unbalanced panel of 198 firms and 1,236 firm-year observations

**TABLE 2**

**Estimation of Citation-weighted patent count *sans* self-citations[a]**

| | Unconditional Fixed-Effects Poisson | | | | |
|---|---|---|---|---|---|
| **Variables** | **Model 1:** | **Model 2:** | **Model 3** | **Model 4** | **Model 5** |
| *Controls* | | | | | |
| Direct ties | -0.00 | -0.01 | -0.00 | -0.01 | -0.01 |
| | (-0.16) | (-0.57) | (-0.48) | (-0.97) | (-0.83) |
| Indirect ties | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (-0.04) | (-0.29) | (-0.44) | (-0.28) | (-0.37) |
| Technological opportunity | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (-0.94) | (-1.04) | (-1.11) | (-1.20) | (-1.21) |
| Technological base (log) | 0.00 | 0.00 | -0.00 | 0.00 | 0.00 |
| | (0.06) | (0.03) | (-0.02) | (0.04) | (0.01) |
| Technological diversity (focal firm) | 1.47 | 1.36 | 1.46 | 1.35 | 1.41 |
| | (1.35) | (1.37) | (1.50) | (1.45) | (1.52) |
| Technological distance (cosine) | -0.82** | -0.79** | -0.82** | -0.86** | -0.86** |
| | (-2.75) | (-2.77) | (-2.87) | (-3.08) | (-3.09) |
| Industry similarity | 0.40* | 0.52** | 0.50** | 0.57** | 0.54** |
| | (2.44) | (2.73) | (2.58) | (3.13) | (3.00) |
| Partners' innovation value | 2.05 | 0.30 | 0.41 | -0.35 | -0.15 |
| | (1.07) | (0.15) | (0.22) | (-0.19) | (-0.08) |
| Technological diversity (alliance partners) | -0.71 | -0.75 | -0.77+ | -0.71 | -0.73+ |
| | (-1.61) | (-1.63) | (-1.70) | (-1.63) | (-1.69) |
| Equity alliance ( % of total alliance) | -0.41 | -0.25 | -0.21 | -0.18 | -0.17 |
| | (-1.13) | (-0.69) | (-0.60) | (-0.50) | (-0.48) |
| Cross-border participants (% of total alliance) | 0.09 | 0.09 | 0.06 | 0.04 | 0.03 |
| | (0.44) | (0.45) | (0.32) | (0.21) | (0.18) |
| Knowledge alliance (% of total alliance) | -0.28 | -0.24 | -0.23 | -0.25 | -0.25 |
| | (-0.82) | (-0.78) | (-0.74) | (-0.84) | (-0.81) |
| Cumulative alliance experience (focal firm) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.07) | (0.41) | (0.17) | (0.33) | (0.20) |
| Average age of alliances | -0.07 | -0.06 | -0.06 | -0.07 | -0.06 |
| | (-1.02) | (-0.90) | (-0.88) | (-1.04) | (-1.00) |
| Acquiror dummy | -0.17 | -0.23+ | -0.20 | -0.21 | -0.20 |
| | (-1.29) | (-1.73) | (-1.50) | (-1.56) | (-1.46) |
| Mergers and acquisitions stock (log) | -0.01 | -0.02 | -0.02 | -0.02 | -0.02 |
| | (-0.85) | (-1.11) | (-1.26) | (-1.14) | (-1.24) |
| Status (Bonacich centrality) | 0.01 | -0.01 | 0.00 | 0.01 | 0.01 |
| | (0.20) | (-0.12) | (0.01) | (0.20) | (0.22) |
| *Independent* | | | | | |
| Structural holes (mean-centered) | | 0.79* | 0.92* | 0.87* | 0.93* |
| | | (2.14) | (2.51) | (2.26) | (2.41) |
| Geographic concentration (mean-centered) | | -0.71* | -0.69* | -0.86** | -0.81* |
| | | (-2.07) | (-2.03) | (-2.67) | (-2.50) |
| Stability (mean-centered) | | -0.14* | -0.26** | -0.24** | -0.29** |
| | | (-2.26) | (-2.96) | (-2.84) | (-3.02) |
| Stability X Structural holes | | | 1.36** | | 0.85+ |
| | | | (2.68) | | (1.69) |
| Stability X Geographic concentration | | | | -1.59* | -1.25* |
| | | | | (-2.51) | (-1.98) |
| *Other* | | | | | |
| Intercept | 4.74** | 4.94** | 4.91** | 4.91** | 4.90** |
| | (5.32) | (6.31) | (6.38) | (6.56) | (6.56) |
| Firm fixed effects | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes |
| Firm-years (*NT*) | 1,236 | 1,236 | 1,236 | 1,236 | 1,236 |
| Firms (*N*) | 198 | 198 | 198 | 198 | 198 |
| Model log-likelihood | -26,368 | -25,703 | -25,490 | -25,403 | -25,334 |
| Wald $\chi^2$ (covariates) | 68.44** | 171.30** | 192.07** | 198.60** | 211.27** |
| d.f. (covariates) | 17 | 20 | 21 | 21 | 22 |

[a] Cluster-robust *z*-statistics in parentheses; two-tailed tests for all variables

+ $p < 0.10$

* $p < 0.05$

** $p < 0.01$

**TABLE 3**

**Estimation of Citation-Weighted Patent Count[a] Controlling for Additional Unobserved Heterogeneity**

| | Random-Effects Poisson | CCRE[b] Dynamic Panel Poisson | CF[c] Approach Poisson Unconditional FE |
|---|---|---|---|
| **Variables** | **Model 6** | **Model 7** | **Model 8** |
| *Controls* | | | |
| Direct ties | -0.01 | -0.01+ | -0.02 |
| | (-0.82) | (-1.76) | (-1.34) |
| Indirect ties | -0.00 | -0.00 | -0.00 |
| | (-0.35) | (-0.75) | (-0.51) |
| Technological opportunity | -0.00 | -0.00+ | -0.00 |
| | (-1.21) | (-1.70) | (-1.26) |
| Technological base (log) | 0.00 | 0.00 | 0.02 |
| | (0.04) | (0.04) | (0.44) |
| Technological diversity (focal firm) | 1.41 | 1.15 | 1.26 |
| | (1.52) | (1.32) | (1.47) |
| Technological distance (cosine) | -0.86** | -0.87** | -0.78** |
| | (-3.10) | (-2.83) | (-2.96) |
| Industry similarity | 0.54** | 0.46* | 0.58** |
| | (3.00) | (2.55) | (3.47) |
| Partners' innovation value | -0.15 | 0.53 | -1.34 |
| | (-0.08) | (0.25) | (-0.56) |
| Technological diversity (alliance partners) | -0.73+ | -0.65+ | -0.99* |
| | (-1.69) | (-1.67) | (-2.11) |
| Equity alliance ( % of total alliance) | -0.17 | -0.33 | -0.10 |
| | (-0.48) | (-0.91) | (-0.28) |
| Cross-border participants (% of total alliance) | 0.03 | 0.19 | 0.06 |
| | (0.19) | (0.94) | (0.32) |
| Knowledge alliance (% of total alliance) | -0.25 | 0.03 | -0.30 |
| | (-0.81) | (0.15) | (-1.02) |
| Cumulative alliance experience (focal firm) | 0.00 | 0.00 | 0.00 |
| | (0.21) | (1.51) | (0.67) |
| Average age of alliances | -0.06 | -0.03 | -0.03 |
| | (-1.00) | (-0.73) | (-0.36) |
| Acquiror dummy | -0.20 | -0.12 | -0.23+ |
| | (-1.47) | (-0.85) | (-1.74) |
| Mergers and acquisitions stock (log) | -0.02 | -0.02 | -0.02 |
| | (-1.24) | (-1.45) | (-1.12) |
| Status (Bonacich centrality) | 0.01 | 0.01 | -0.04 |
| | (0.21) | (0.36) | (-0.84) |
| *Independent* | | | |
| Structural holes (mean-centered) | 0.94* | 0.65* | 2.47* |
| | (2.45) | (2.26) | (2.14) |
| Geographic concentration (mean-centered) | -0.81* | -0.25 | -0.66+ |
| | (-2.51) | (-0.64) | (-1.94) |
| Stability (mean-centered) | -0.29** | -0.26** | -0.30** |
| | (-3.03) | (-3.35) | (-3.19) |
| Stability X Structural holes | 0.85+ | 0.96* | 0.87+ |
| | (1.70) | (1.98) | (1.72) |
| Stability X Geographic concentration | -1.25* | -0.78+ | -1.47* |
| | (-1.98) | (-1.73) | (-2.10) |
| *Other* | | | |
| Citation-weighted patent count *sans* self-citations$_{-1}$ | | 0.00** | |
| | | (2.74) | |
| First-stage fixed effects residuals | | | -1.57 |
| | | | (-1.22) |
| Intercept | 5.85** | 4.61** | 5.69** |
| | (8.78) | (3.96) | (7.91) |
| Firm fixed effects[d] | No | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Firm-years ($NT$) | 1,236 | 1,236 | 1,236 |
| Firms ($N$) | 198 | 198 | 198 |
| Model log-likelihood | -26,064 | -23,773 | -25,115 |
| Wald $\chi^2$ (covariates) with d.f. = 22 | 214.62** | 176.59** | 279.48** |

[a] z-statistics in parentheses using panel-robust standard errors; two-tailed tests for all variables

[b] The conditionally correlated random effects dynamic panel Poisson model

[c] Control function or two-stage residual inclusion approach for the unconditional fixed effects Poisson model

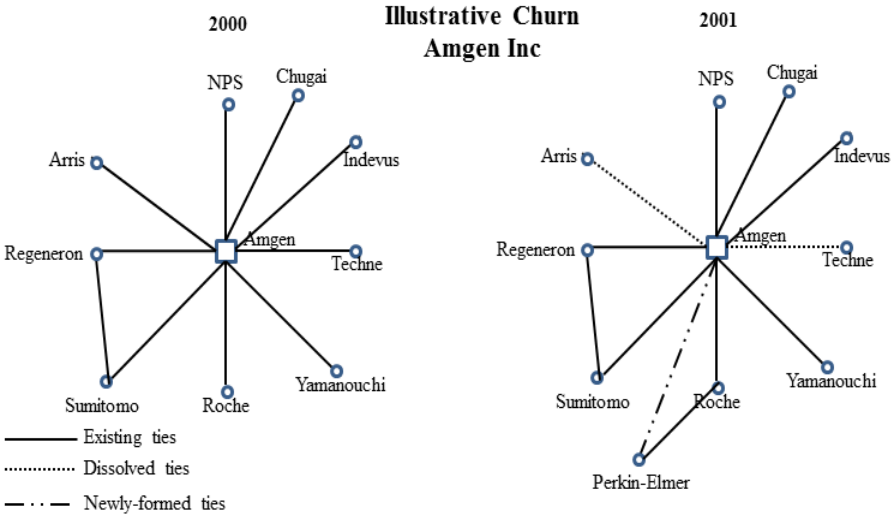
[d] Estimated using initial conditions in Model 7

+ $p < 0.10$

* $p < 0.05$

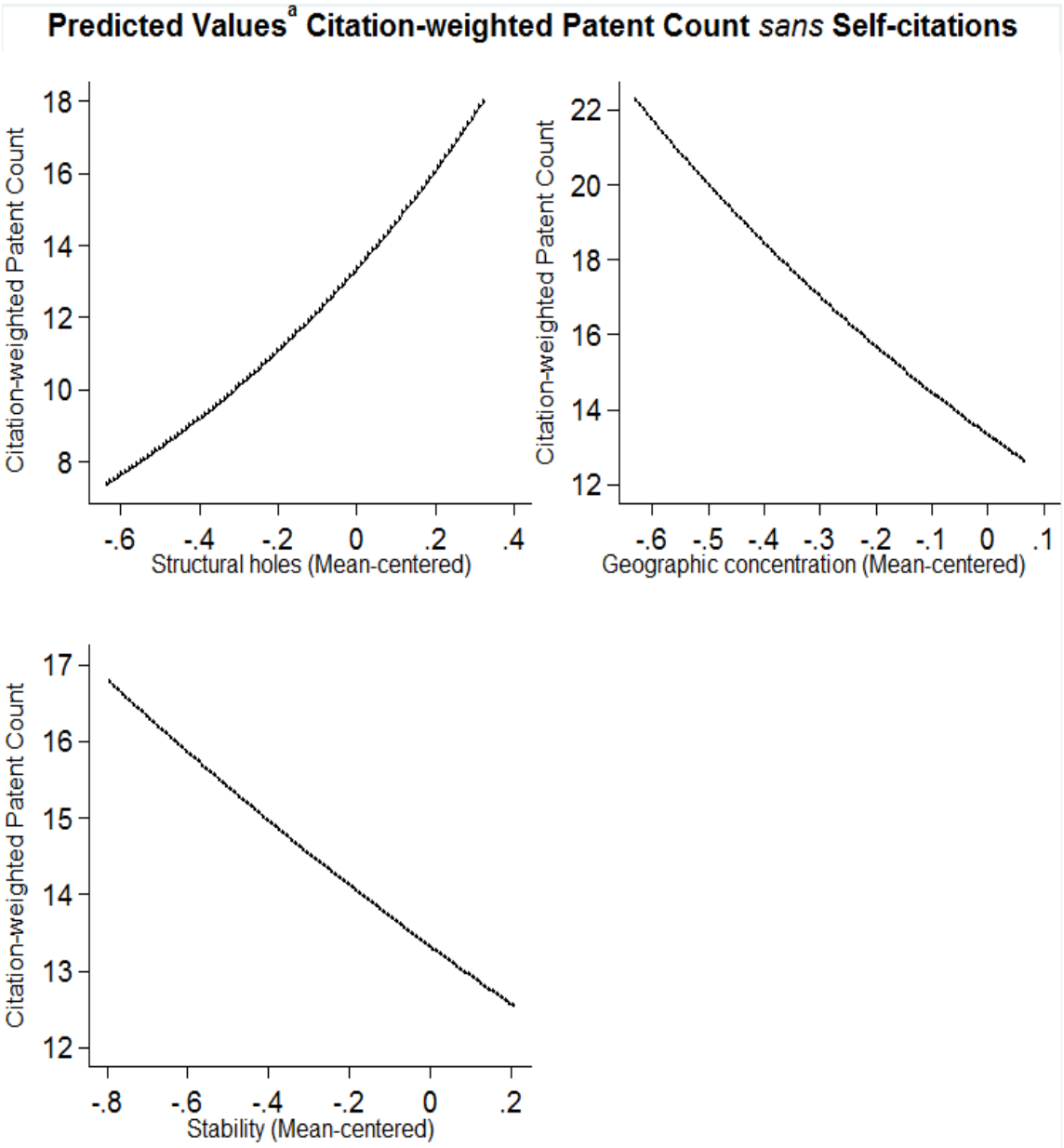
** $p < 0.01$

# FIGURE 1



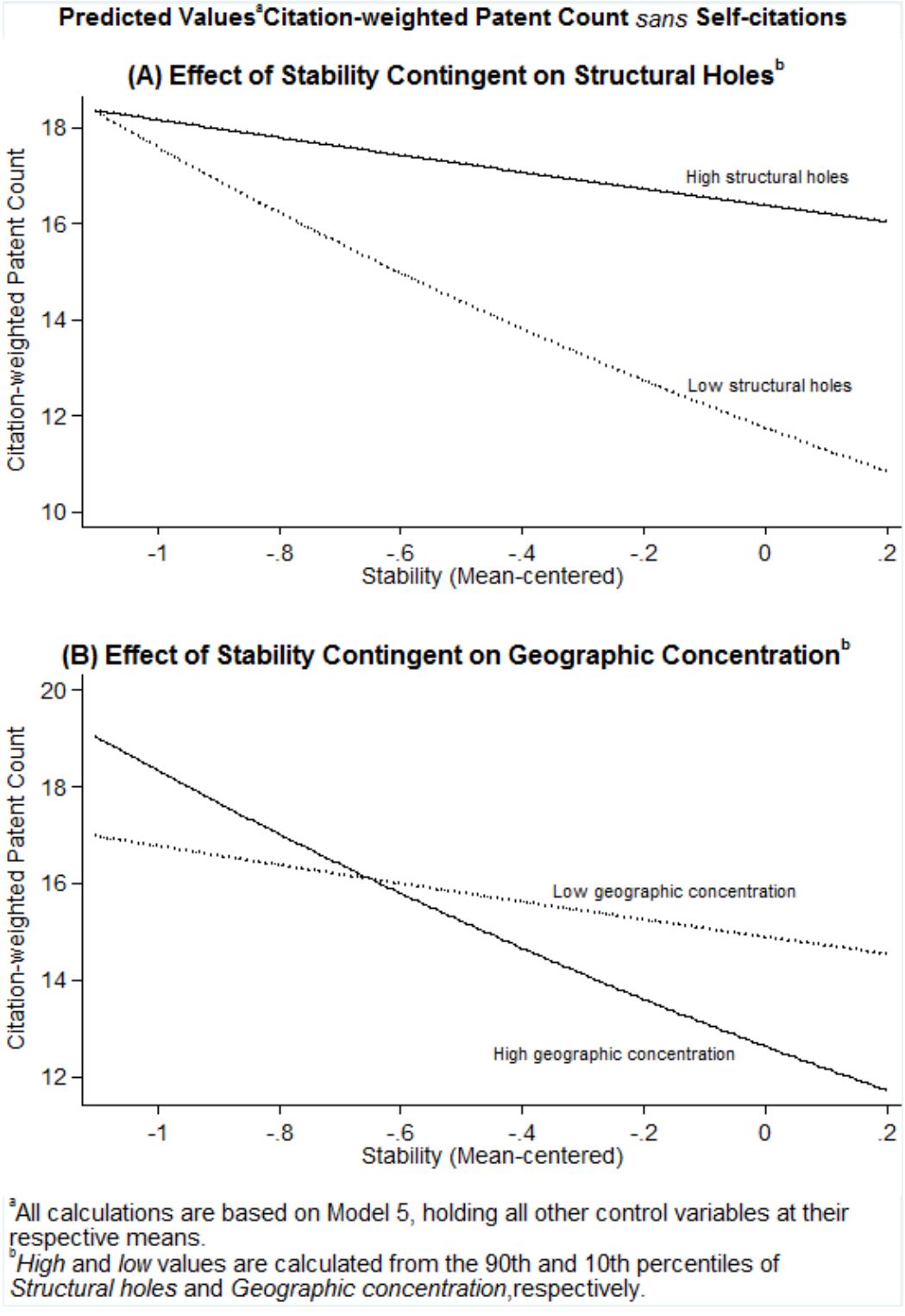

| Observation period | Ties added (a) | Ties lost (b) | Total change (c) = a + b | Total unique ties (d) | Churn 2001 (e) = c / d | Stability (f) = 1 - e |
|---|---|---|---|---|---|---|
| 2000-2001 | 1 (Perkin-Elmer) | 2 (Arris, Techne) | 3 (=1+2) | 10 (Arris, NPS, Chugai, Indevus, Techne, Yamanouchi, Roche, Perkin-Elmer, Sumitomo, & Regeneron) | 0.3 (=3/10) | 0.7 (= 1- 0.3) |

**FIGURE 2**




[a]Across observed range of *Structural holes*, *Geographic concentration*, and *Stability*, holding all other variables at their respective means

**FIGURE 3**




[a]All calculations are based on Model 5, holding all other control variables at their respective means.
[b]*High* and *low* values are calculated from the 90th and 10th percentiles of *Structural holes* and *Geographic concentration*,respectively.

**Appendix 3: Estimation of Citation-weighted patent count *sans* self-citations[a] (robustness check)**

| | Unconditional Fixed-Effects Poisson | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Model 1: Fully specified** | **Model 2: Direct ties** | **Model 3: Status** | **Model 4: Partner value** | **Model 5: All gone** | **Model 6: R&D Intensity** |
| *Controls* | | | | | | |
| Direct ties | -0.01 | | -0.01 | -0.01 | | -0.01 |
| | (-0.83) | | (-0.59) | (-0.85) | | (-0.83) |
| Indirect ties | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (-0.37) | (-0.16) | (-0.35) | (-0.37) | (-0.14) | (-0.37) |
| Technological opportunity | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (-1.21) | (-1.25) | (-1.10) | (-1.21) | (-1.15) | (-1.21) |
| Technological base (log) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.01) | (0.02) | (0.00) | (0.00) | (0.02) | (0.01) |
| Technological diversity (focal firm) | 1.41 | 1.45 | 1.42 | 1.41 | 1.45 | 1.41 |
| | (1.52) | (1.53) | (1.51) | (1.51) | (1.53) | (1.52) |
| Technological distance (cosine) | -0.86** | -0.83** | -0.85** | -0.86** | -0.84** | -0.86** |
| | (-3.09) | (-3.09) | (-2.99) | (-3.09) | (-3.02) | (-3.09) |
| Industry similarity | 0.54** | 0.54** | 0.54** | 0.54** | 0.55** | 0.54** |
| | (3.00) | (2.98) | (2.79) | (2.89) | (2.75) | (3.00) |
| Partners' innovation value | -0.15 | 0.05 | 0.02 | | | -0.14 |
| | (-0.08) | (0.03) | (0.01) | | | (-0.08) |
| Technological diversity (alliance partners) | -0.73+ | -0.76+ | -0.74+ | -0.73+ | -0.76+ | -0.73+ |
| | (-1.69) | (-1.80) | (-1.67) | (-1.67) | (-1.79) | (-1.68) |
| Equity alliance ( % of total alliance) | -0.17 | -0.18 | -0.17 | -0.17 | -0.18 | -0.17 |
| | (-0.48) | (-0.51) | (-0.48) | (-0.49) | (-0.56) | (-0.48) |
| Cross-border participants (% of total alliance) | 0.03 | 0.05 | 0.03 | 0.03 | | 0.03 |
| | (0.18) | (0.26) | (0.17) | (0.17) | | (0.18) |
| Knowledge alliance (% of total alliance) | -0.25 | -0.25 | -0.25 | -0.24 | -0.25 | -0.25 |
| | (-0.81) | (-0.81) | (-0.83) | (-0.80) | (-0.82) | (-0.81) |
| Cumulative alliance experience (focal firm) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.20) | (0.02) | (0.18) | (0.18) | (0.01) | (0.20) |
| Average age of alliances | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 |
| | (-1.00) | (-0.96) | (-0.98) | (-0.99) | (-0.96) | (-1.00) |
| Acquiror dummy | -0.20 | -0.20 | -0.20 | -0.20 | -0.20 | -0.20 |
| | (-1.46) | (-1.53) | (-1.42) | (-1.45) | (-1.50) | (-1.46) |
| Mergers and acquisitions stock (log) | -0.02 | -0.02 | -0.02 | -0.02 | -0.02 | -0.02 |
| | (-1.24) | (-1.23) | (-1.24) | (-1.23) | (-1.24) | (-1.23) |
| Status (Bonacich centrality) | 0.01 | -0.00 | | 0.01 | | 0.01 |
| | (0.22) | (-0.10) | | (0.22) | | (0.22) |
| R&D intensity | | | | | | 0.00 |
| | | | | | | (0.25) |
| Employee (log) | | | | | | |
| *Independent* | | | | | | |
| Structural holes (mean-centered) | 0.93* | 0.93* | 0.95* | 0.93* | 0.92* | 0.93* |
| | (2.41) | (2.40) | (2.57) | (2.37) | (2.56) | (2.41) |
| Geographic concentration (mean-centered) | -0.81* | -0.76* | -0.80** | -0.81* | -0.76* | -0.81* |
| | (-2.50) | (-2.36) | (-2.59) | (-2.55) | (-2.37) | (-2.49) |
| Stability (mean-centered) | -0.29** | -0.29** | -0.29** | -0.29** | -0.29** | -0.29** |
| | (-3.02) | (-3.07) | (-3.05) | (-3.02) | (-3.14) | (-3.02) |
| Stability X Structural holes | 0.85+ | 0.91+ | 0.84+ | 0.85+ | 0.92+ | 0.85+ |
| | (1.69) | (1.77) | (1.69) | (1.75) | (1.87) | (1.69) |
| Stability X Geographic concentration | -1.25* | -1.18+ | -1.22* | -1.25* | -1.18* | -1.25* |
| | (-1.98) | (-1.87) | (-2.21) | (-2.10) | (-2.07) | (-1.98) |
| *Other* | | | | | | |
| Intercept | 4.90** | 4.90** | 4.91** | 4.90** | 4.90** | 4.90** |
| | (6.56) | (6.59) | (6.91) | (6.74) | (6.93) | (6.56) |
| Firm fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm-years (*NT*) | 1,236 | 1,236 | 1,236 | 1,236 | 1,236 | 1,236 |
| Firms (*N*) | 198 | 198 | 198 | 198 | 198 | 198 |
| Model log-likelihood | -25,334 | -25,361 | -25,338 | -25,334 | -25,362 | -25,334 |
| Wald $\chi^2$ (covariates) | 211.27** | 172.22** | 210.86** | 210.05** | 162.71** | 211.19** |
| d.f. (covariates) | 22 | 21 | 21 | 21 | 19 | 23 |

[a] Cluster-robust z-statistics in parentheses; two-tailed tests for all variables

+ $p < 0.10$

* $p < 0.05$

** $p < 0.01$

# CHAPTER 3

## Origins of Ego-Network Stability: A Deeper Look into Brokerage (Structural Hole) Stability

That friends, however friends they were,
Still deal with things as things occur,
And that, excepting for the blind,
What's out of sight is out of mind.
-- *The Poems of Arthur Hugh Clough*

In the previous chapter, I underscored the salience of network stability in order to understand better the network structure-performance link. Two key insights from Chapter 2 provide motivation for this chapter. First, stability negatively affects the focal firm's innovation performance. Second, spanning structural holes mitigates the negative effect of stability. Given the importance of structural holes in reducing the negative effect of stability, I in this follow-up chapter examine what makes structural holes or brokerage structures stable or persist in the first place. In this regard, in this chapter, I limited the domain of stability to brokerage stability rather than ego-network stability. This change in direction from the previous chapter is an essential first step to open the black box of ego-network stability. My brokerage-stability focus is valuable for further in-depth examination of basic network structures without confounding the stability arising from the open or brokerage-structure configurations with that from the closed-structure configurations. Put another way, the ego-network stability in the previous chapter may arise from closure as well as brokerage. Since the implications of these two structures are quite different, a sole focus on the brokerage structure allows me to get directly at the antecedents of stability, without any ambiguity about whether or not the network

structure configuration per se, i.e., brokerage or closure, is the source of stability. I provide additional theoretical rationale for investigating the antecedents of stability of these brokerage structures in the following paragraphs.

In general, recent scholarship investigates the formation and outcomes of organizational networks, but has paid scant attention to the factors that make these structures dissolve or persist (Watts, 2001; Kim, Oh, & Swaminathan, 2006; see Gulati & Gargiulo, 1999 for an exception). Emphasizing both network creation and stability in his early work calling out network evolution, Jarillo (1988: 36) originally raised the question, "How can a network be created and sustained?" At the same time, in addition to their embeddedness in social or organizational contexts (Granovetter, 1985), firms and inter-firm ties are embedded in geographic space, an infrequently examined factor in the network literature (Ter Wal, 2014; Cattani, Pennings, & Wezel, 2003). By ignoring geographic embeddeddness, researchers risk misattributing geography's effect on network evolution to nodal, structural, or tie attributes (Gastner & Newman, 2006; for exceptions see Bell & Zaheer, 2007; Whittington, Owen-Smith, & Powell, 2009; Kono, Palmer, Friedland, & Zafonte, 1998).

In this chapter I address the issue of brokerage stability from the perspective of the interfirm network's embeddedness in geographic space. For both theoretical exposition and empirical validation, I use a structural hole – or brokerage – triad as my unit of analysis and assess the effects of geography on triadic stability. The triad is often viewed as the basic building block of a network (Simmel, 1950; Krackhardt, 1999; Madhavan & Gnyawali, 2004). In structural hole or brokerage triads, a focal firm

connects to two disconnected alter firms (Burt, 1992), often acting as a "knowledge broker" in alliance networks. Much research on inter-organizational alliance network has shown the unique benefits of brokerage in accessing new knowledge (Hansen, 1999; Bell & Zaheer, 2007) and good ideas (Burt, 2004).

At the same time, structural holes are believed to be transient (Burt, 2002; Krackhardt, 1998). Brokerage positions, while allowing for exploitation of information asymmetries, may also generate distrust towards the broker (Stovel, Golub, & Milgrom, 2011). The broker might choose to play one alter firm off against the other to maximize "knowledge rents," in so doing undermine the trust of the alters in the broker. Alters' effort to reduce unfavorable dependence on the broker once they become aware of each other, and of the true nature of the broker's role, might cause the brokerage triad to decay (Buskens & van de Rijt, 2008). In this study I seek to understand when and why brokerage triads persist, and conversely, the factors that might hasten their termination in geographic space, given that knowledge, including knowledge of the broker's role, as well as of the potential gains to alters from closing the hole, may be geographically constrained. Furthermore, recent research shows that technology development triads are more successful when 'group cycling' exists, isolating each dyad to work together at a time towards the triad's overall goals (Davis, 2016). Geography may help maintain this decomposition.

I define a brokerage triad to be stable if there is no change in its membership for a certain period *t*. A brokerage triad becomes unstable or decays if any of its members leave, or if its unconnected members form a new relationship between themselves (Burt,

2002). Prior studies examining the role of geographic proximity on networks have ignored its effect on network change, focusing principally on tie formation (Bossard, 1932; Blau, 1977). With a principal focus on the role of technological regimes, Ter Wal (2014) examines how effects of geography and triadic closure on tie formation are modified with a change in the technological regime. Building on these contributions, my point of departure is the direct effect of geography on brokerage stability.

At the same time, research finds that the membership of firms in network communities influences their likelihood of forming bridging ties (Sytch, Tatarynowicz, & Gulati, 2012). Network communities are tightly knit mutually exclusive social collectivities with increased interdependence and denser ties within the community than across communities (Hawley, 1950; Tatarynowicz, Sytch, & Gulati, 2016). However, the issue of triadic stability when the broker and alter firms reside in different network communities remains an open question. Compared to those from different communities, alter firms from same network communities might avail brokerage benefits because of positive network externalities, enhancing brokerage stability (Clement, Shipilov, & Galunic, 2017). Consistent with the underlying logic, I argue that inter-community competition places a severe strain on brokerage relationship, reducing triadic stability (Gomes-Casseres, 1994). In sum, I investigate two related questions: *How does geography affect the stability of brokerage structures? Also, how do firms' memberships in network communities affect brokerage stability?*

I empirically test my hypotheses with interfirm alliances in the global pharmaceutical industry context from 1985 to 2005 using 61,495 brokerage triad-year

observations and discrete time survival models with complementary log-log estimators. Consistent with my sample, log-log estimators work well with both high frequency and rare events data, and are invariant to the choice of the interval to measure survival times (as I explain in the Methods section) (Allison, 2010). In addition, such models also allow me to independently analyze different operationalizations of brokerage decay with competing risk models (Allison, 2014) in robustness checks.

Below, I develop my hypothesis elucidating the link between brokerage stability and geography in terms of the triadic evolutionary outcome of decay. Thereafter, I develop arguments and hypothesize about the effect of the broker and alter firms' embeddedness in different network communities on brokerage stability.

## THEORY AND HYPOTHESES

### Geographic Distance and Brokerage Stability

*Prima facie*, geographic distance might seem to reduce brokerage stability because of the costs associated with distance (Zaheer, 1995). Distance makes it harder to establish trust between alliance partners. Also, geographic distance might make the alliance less resilient to 'shocks' to relationships, with conflicts more likely to escalate because of the lack of frequent efficient communication and interaction. However, I argue that these issues, though relevant, are more critical during the initial decision-making process about whether or not to form an alliance across distant geographies. Once partner firms self-select into the alliance relationship, these factors might not reduce stability because of relationship-specific investments (Subramani & Venkatraman, 2003).

Also, at the brokerage-triad level, the presence of the third party changes the dynamics at the dyad level. Situating dyadic relationships in a triadic context creates "quite dramatic changes in seemingly stable relations" (Gadde & Mattsson, 1987: 29) and vice versa.

Next, I develop arguments with respect to the effect of geographic distance on the stability of the brokerage triad through three sets of related arguments: brokerage awareness; search, monitoring, coordination and communication costs; and knowledge heterogeneity.

***Brokerage awareness.*** My starting point in this line of argument is that a brokerage triad is likelier to be stable if alter firms remain unaware of brokerage (Burt, 2005). Otherwise, alter firms might strategically manipulate their networks to increase the benefits derived from them (Watts, 1999) by either terminating the disadvantageous alliance with the broker or possibly seeking better collaboration opportunities within and beyond the triad. In other words, for the brokerage triad to decay, the two alter firms must be aware of each other's existence and, subsequently, each other's relationship with the broker (Hahl, Kacperczyk, & Davis, 2016).

Lack of geographic proximity decreases the visibility of actors present in the spatial milieu, reducing chance encounters (Blau, 1977; Hillier & Penn, 1991). Alter firms might know so little about each other that they are less likely to discover that the broker firm extracts a surplus from their relationships. Their lack of knowledge about brokerage is likely to promote the continuity of the status quo in the broker-alter firm triad. At the same time, the formal and informal interactions between broker and alter

firms decrease with geographic distance (Saxenian, 1996a), reducing the chances of intentional or unintentional leaks of information regarding brokerage. Furthermore, inventor mobility may be constrained by distance, making it less likely that a scientist from the broker firm is hired by any of the alter firms (Almeida & Kogut, 1999; Almeida, Dokko, & Rosenkopf, 2003; Breschi & Lissoni, 2009). In addition, spatially distant broker and alter firms might not share the same industry and professional associations, diminishing the possibility of knowing about the brokerage via a third party. Thus, distant alter firms have little leeway to be cognizant of brokerage, enhancing the stability of the brokerage triad.

Spatial barriers to the flow of information may seem to be at odds with recent advances in electronic communication and high speed transportation. However, even online networks have been shown to be spatially constrained (Liben-Nowell, Novak, Kumar, Raghavan, & Tomkins, 2005). Goldenberg and Levy (2009) show that, though the quantum leaps in the information technology have increased the total volume of communication, local social ties have seen most of the increases in the communication volume. Allen (2007) finds that the probability of communication between two product development engineers decreases rapidly with growing distance between their offices. Locational proximity enhances quick and dynamic feedback mechanism between actors in which each party is aware of other's world view (Nohria & Eccles, 1992), thereby increasing the chances of brokerage detection and the likelihood of brokerage decay.

***Search, monitoring, coordination, and communication costs.*** Furthermore, in light of the well-established findings about the geographically-bounded nature of knowledge (e.g. Almeida & Kogut, 1999), geography-induced information insulation increases alter firms' search costs. Such search costs would constrain firms' ability to obtain detailed information about each potential partner's characteristics relevant for the new alliance between them even when one alter firm is on the other's radar (Geertz, 1978). This is even more so for knowledge-based alliances because of the uncertainty inherent in R&D projects regarding their fruitful completion (Nicholson, Danzon, & McCullough, 2005). In addition, each alter firm cannot *ex ante* share each other's knowledge to reduce the information uncertainty because doing so might itself unintendedly reveal proprietary knowledge (Arrow, 1962; Kogut & Zander, 1993). Geographic distance may also make the ex post monitoring of the partner's opportunistic behavior difficult or costly because of information asymmetry, increasing the hazard of adverse selection in alliance partnering (Reuer & Lahiri, 2014).

Even when alter firms have perfect information about partner attributes, an alter firm would strategically form a tie with the other unconnected alter firm to gain an advantage over the broker only when the *expected* benefits of tie formation and maintenance in terms of knowledge generation and transfer exceed the expected costs. Seen through a geography lens, when alter firms form a tie with each other, not only do they form a social relation but also they connect two different geographies within which they are situated. There are extra coordination and communication costs to maintaining

such a tie that traverses distant geography over and above the costs of 'regular' tie formation and maintenance. Increased geographic distance translates to increased travel and transportation costs, increasing the costs of maintaining ties across geographies (Bell & Zaheer, 2007).

More importantly, proximity leads to informal high quality communication (Hagstrom, 1965). As much of the knowledge relevant for innovation is tacit, proximity has an advantage in avoiding transmission loss via multiple face-to-face interactions (Mok, Wellman, & Vasu, 2007). Saxenian (1996a) provides evidence for the relationship between locational proximity and ease of interaction among knowledge workers in the Silicon Valley, facilitating knowledge flow and improving their innovativeness relative to those from Route 128. Thus, physical proximity allows for frequent, high quality communication at low cost (Kraut, Egido, & Galegher, 1988).

Also, distance adds to the coordination time and the travel time of concerned parties (Boeh & Beamish, 2012). Jeffrey Kalb, the founder of MasPar Computer Corporation, in his interview with Saxenian (1996b: x) makes similar arguments: "It's not one thing, but if you spend lots of time on airplanes and on the phone, playing phone tag, you can get an overall 20-30 percent slowdown in time to market." Thus distance, in general, increases the cost of tie formation because of coordination costs, reducing the likelihood of decay.

***Knowledge heterogeneity.*** Further, although prior research has pointed to the existence of brokerage advantages for the broker firm, the *persistence* of brokerage

advantages is a more subtle and less studied idea. The persistence of brokerage benefits stems from the continuing heterogeneity in alter knowledge bases, particularly between alters that are geographically distant. Spatially distant alter firms may exhibit continued knowledge base heterogeneity for two main reasons. First, alter firms separated by geographic distance may face idiosyncratic situations arising from distinct local needs and resource availability (Ahuja & Katila, 2004). Also, geographically separated alter firms might pursue different trajectories for knowledge development in order to adapt to differing local cultures, administrations, and economies (Ghemawat, 2001; Abernathy & Utterback, 1978). Second, knowledge is sticky (von Hippel, 1994), and knowledge spillovers, though possible, are localized or geographically bounded, with spillover effects occurring in close geographic proximity to where the knowledge originated (Jaffe, Trajtenberg & Henderson, 1993; Jaffe, 1989). This knowledge stickiness enables knowledge diversity to persist between unconnected but distant alter firms. Such knowledge diversity between broker and alters allows the broker to maintain continued access to new knowledge over an extended period (Das & Teng, 2003), reducing the possibility of hole decay.

In sum, geographic distance between alter firms enhances brokerage stability because it becomes more likely that brokerage remains hidden from the eyes of alter firms, because it is costly for alters to form a new tie, and because the broker maintains continued access to knowledge diversity. Thus, I posit that

*Hypothesis 4. Conditional on firms' membership in a brokerage triad, the greater the geographic distance of firms from one another in the brokerage triad, either a) the geographic distance between alter firms, or b) the geographic distance between a broker and the alters, the lower the likelihood that the brokerage triad (structural hole) decays, and therefore, greater the triadic stability.*

**Membership in Different Communities and Brokerage Stability**

Next I develop the rationale for brokerage stability when the brokerage triad's members are located in the same network community and conversely, instability when they are located in different communities. Network communities or "networks within networks" are mutually exclusive social collectivities with greater tie density within structural groups than between them (Tatarynowicz et al., 2016). Communities are seen as "mesolevel" structures that may exist between dyads and networks (Rowley, Greve, Rao, Baum, & Shipilov, 2005). I use the term "communities" in the same way as researchers have used "clusters" (Knoke, 2001; 2009), "constellations" (Lorenzoni & Ornati, 1988), "blocks" (Zhang & Zhang, 2006), "cliques" (Wasserman & Faust, 1994) and "groups" (Rowley, Baum, Shipilov, Greve, & Rao, 2004) in their analyses of social systems. I base my theoretical explanation regarding the effect of triad members' citizenship in both the same and different communities by drawing on recent research on brokerage as a public good (Clement et al., 2017), the threat of community sanctions, and the costs imposed by inter-community competition.

***Brokerage as a public good.*** When brokers and alter firms are located in the same community, they form part of a broader cohesive group. In such a group, dense connections are reinforced by previous joint work experience and interactions (e.g. Singh, 2005).The structural disconnect of the community from other groups and non-group members in the network structure results in the development of shared norms, language and routines within the community that are quite different from those within other communities. Community members identify themselves more as part of the community than as part of the whole network (Knoke, 2009). They exhibit homophilous tendencies, mostly limiting their search of opportunities and partners to those within community boundaries (Gulati & Gargiulo, 1999, Ahuja, Polidoro, & Mitchell, 2009). In this vein, community members are network neighbors (Paxton & Moody, 2003). Similar identities and dense ties breed trust within the community (Rowley et al. 2005; Zaheer, McEviley, & Perrone, 1998).

Seen through a community lens, in a cohesive group with an environment of reciprocity, a broker might be more willing to share the surplus from brokerage with alter firms within the network community than it would be had alter firms been located outside its community. Extant work importantly points out that brokerage is in part a public good (Fernandez-Mateo, 2007) in that its positive benefits might spill over to the broker's network neighborhood (Galunic, Ertug, & Gargiulo, 2012). The positive externalities thus generated become more salient when alter firms are located within the same community as the broker's, especially in the knowledge creation contexts (Clement et al., 2017).

Since alter firms are able to tap into the brokerage benefits indirectly via community linkages, the brokerage triad is less likely to decay.

***Threat of sanctions.*** A cliquish structure among community members enables more efficient governance and control for those within the group than those outside (Coleman, 1988). The dense ties among community members and the ensuing social monitoring weakens the insulation that the brokerage position provides in terms of playing one alter firm against the other or reducing commitment to any party at will. In this regard, a broker's opportunistic behavior might not remain unsanctioned. In other words, brokerage triad members' location in the same network neighborhood creates a reputational lock-in for the broker, reducing its chances of engaging in self-seeking behavior (Greif, 1989). A related element of triad members' positioning within the same community is mutual dependence and a symbiotic relationship (Ryall & Sorenson, 2007; Sytch et al., 2012). These factors also contribute toward making the triadic relationship more equitable and, in turn, less likely to decay. The threat of sanctions, exclusion, and mutual dependence result in keeping the brokerage triad stable.

***Inter-community competition.*** In contrast, competition exists between communities (Gomes-Casseres, 1994; 1996). In the case of brokerage triad members' location in different communities, even though the alter firms might not be aware of each other, they are wary of the broker because of its location in a different community, affecting the broker's maneuvering abilities. Intense competition between the broker firm's community and alter firm's communities makes the broker's task of managing

alters from multiple communities more challenging. In this regard, the broker firm's embeddedness in a different community might add to the tension the broker already faces by virtue of spanning a brokerage position between two competing alters. The broker firm might find itself entangled among the norms and standards of the multiple communities in which its alters are positioned, affecting its control benefits. Alter firms are more likely to challenge the broker's authoritative position which does not derive from alter firms' community norms. Thus, alter firms from different communities are more likely to engage in opportunistic behavior, increasing the cost of maintaining a brokerage relationship. In the extreme case community authority might trump the broker's authority, and the broker's ability to benefit from being connected to two unconnected alters might be marred by community-level competition and the ensuing mistrust. Thus, the location of brokerage triad members in different network communities makes the cost of maintaining the brokerage relationship excessive, prompting a breakdown of the brokerage structure. Hence,

> *Hypothesis 5. Conditional on firms' membership in a brokerage triad, the brokerage triad firms' (broker and alter firms') membership in different network communities increases the likelihood of brokerage triad (structural hole) decay, thereby decreasing triadic stability.*

# METHODS

## Data and Sample

Some discussions in this section are repetitions from Chapter 2. However, I briefly reprise them here to maintain the flow in the story. I use the global pharmaceutical industry context with 4-digit SIC codes (2833: Medicinal chemicals; 2834: Pharmaceutical preparations; 2835: Diagnostic substance; 2836: Other biological products) to test my hypotheses. Pharmaceutical companies invest between $1.5 billion to $1.8 billion in R&D for a successful drug (DiMasi, Hansen, & Grabowski, 2008) and yet it takes 10-15 years to successfully develop one (PhRMA, 2013). According to the U.S. Food and Drug Administration (FDA, 2015), "…only 5 in 5,000 compounds that enter preclinical testing make it to human testing, and only 1 of those 5 may be safe and effective enough to reach pharmacy shelves." Finding a new molecule entails spanning diverse disciplines as chemistry, biology, and clinical studies (Loging, Harland, & Williams-Jones, 2007). Under such circumstances it is difficult for any pharmaceutical firm to undertake the entire discovery project by itself. Alliances, mostly in R&D, are commonplace in the pharmaceutical industry (Hoang & Rothaermel, 2005), enabling me to create the alliance brokerage network and extract structural hole triads.

Starting with the Thomson Reuters SDC Platinum database on joint ventures and alliances, I chose both public and private firms in the global pharmaceutical industry with at least one alliance announced between 1980 and 2005. Alliances were rare prior to 1980, thus alleviating left censoring bias. I used archival databases such as *Factiva,*

*LexisNexis, and SEC-EDGAR* to further supplement this information. Next, I set the network boundary using two criteria (Laumann, Marsden, & Prensky, 1989; Gulati, 1995b). First, both alliance partners must belong to the pharmaceutical industry (Rowley, Behrens, & Krackhardt, 2000). Second, I required that the alliance context must be pharmaceutical as determined by its primary four-digit SIC code. I used all alliances types because any type of alliance relationship might contribute to knowledge transfer (Schilling & Phelps, 2007). Next, I aggregated the alliance information for all subsidiaries (at least 50% stock ownership) at the ultimate parent level, and further adjusted for name changes, mergers and acquisitions, and restructuring using numerous databases such as *Lexis Nexis Corporate Affiliations, Dun & Bradstreet's Who Owns Whom, Pharma & MedTech Business Intelligence, Bloomberg, and Thomson Reuters SDC Platinum Mergers & Acquisitions databases.*

To compute alliances' termination dates, I created a master dataset with detailed information on alliance deals by combining archival data from multiple sources such as *Factiva, LexisNexis, NASDAQ - Datastore, Bloomberg Professional Terminal, SEC-EDGAR,* and *Mergent Online.* In addition, I used trade magazines and journals such as *Chemical marketing reporter* and *Japan Chemical Week*; news sources such as *Dow Jones News Service, PR Newswire, BioCentury, PharmaTimes, Strategic Transactions :: Pharma & Medtech Business Intelligence,* and *Pharmaceutical Online*; and firm websites. This comprehensive data collection effort helped me drop those alliances that were announced but did not come to fruition. Also, in case of alliances with multiple

partners, it allowed me to delineate whether all of the partners involved had alliances with each other or just one firm had alliance with all others. Next, I derived termination dates using a multi-pronged strategy described below.

First, I identified alliance termination dates which were explicitly mentioned in my deal master dataset. I further searched for alliance extensions or new alliances in these cases to ascertain when the relationship between two partners actually ended. Second, in case of open-ended alliances, a majority in my context, with no predetermined termination dates, I engaged in a deep web search using multiple variants of the word "end," "termination," "dissolve," "complete," "break," "leave," "withdraw," along with partners' names with or without drug or disease names and, in addition, accounted for any alliance extensions or additions between partners. It was relatively easy to search for joint venture termination dates using their names as stated in the deal (Ahuja, 2000).

Third, from my master dataset with deal texts, I identified drug names, brands and formulations, key pharmaceutical compounds, and disease and used them as search queries in additional databases such as *Adis Insight*, treating the date of discontinuation of a drug or trial by the firm as the alliance termination date if the partners did not form any new alliance. Fourth, I followed the alliance progress using *Factiva*, company annual reports, and SEC filings until these sources stopped mentioning the deal, which then I record as its termination year. I did not follow this approach when these databases discussed alliances in only one year without any explicit mention of termination news. Fifth, I tracked mergers and acquisitions as well as structural reorganizations, and

revalidated the alliance's existence if the new partners continued with the prior relationship. Sixth, I scanned important life events such as NASDAQ listings and CEO interviews post award-winning to find deal termination dates. My search followed a sequential process in that I moved to the next step only when I was not able to find termination data in the previous step.

Next, based on alliance duration from my termination dataset, for each year I created symmetric adjacency matrices or networks of alliance ties. From the network thus created, I extracted structural hole or brokerage triads using a hand-written code in STATA 13. The results were further validated using Pajek64 4.02. To illustrate by an example, I evaluate in Figure 4 whether firm B is a broker or not from B's ego-network using two different scenarios, 1 and 2. As seen in the figure, in scenario 1, all the alter firms, A, C, and D, are connected with each other. Hence, firm B is not a broker firm and will not appear in my final observation. In contrast, in scenario 2, B is a broker because B spans two open triads ABC and ABD respectively.

Then, I collected data on latitudes and longitudes of all member firms of structural hole triads to calculate geographic distances. Using firms' exact addresses, I employed geocoding to retrieve the latitude and longitude via the Google Geocoding Application Program Interface. For cases in which the geocoding algorithm did not provide exact latitude and longitude or only provided location degrees at the country level, I further hand collected the data inputting firms' complete addresses in Google maps. In all, my final sample with complete information on the independent variables consists of 17,212

unique brokerage triads with 61,495 triad-year observations involving 329 broker firms and 680 alter firms over a 21-year period.

## Dependent Variable

***Decay.*** My dependent variable *Decay* is a dummy. Recall that I consider a brokerage triad to be stable if both the membership of the triad and the linkages among the triad members stay the same for a certain duration *t*. As can be seen in Figure 5, the brokerage triad *BAC* is stable at time *t1* and at *t2* because broker firm *A* continues to connect to the same unconnected alters *B* and *C*, with no change in relationships among *A*, *B*, and *C* during these two periods. I assign a value of *0* to the dummy if the brokerage triad appeared for the first time for a particular year. For other years, the dummy retains the value of zero if the triad appears consecutively in each year since its first appearance. The triad decays if either its members do not continue the existing relationship or its unconnected members form a new relationship between them in the next year. I operationalize *Decay* as *1* for the year in which the triad decays. To minimize potential simultaneity, I lag my explanatory variables by one year.

## Independent Variables

***Alter-alter geographic distance (in thousand miles).*** I used the spherical law of cosines formula to calculate the great-circle distance between the two alter firms' subsidiaries (or the alter firm themselves) which had an alliance with a common broker firm at time *t* (Sorenson & Audia, 2000; Funk, 2014; Reuer & Lahiri, 2014).

$$distance_{pqt}=R\{\arccos[\sin(lat_{pt})\sin(lat_{qt})+$$

$$\cos(lat_{pt})\cos(lat_{qt})\cos(long_{qt}-long_{pt})]\}$$

where $R$ =3,956.54 miles is the radius of the earth; $lat_{pt}$ and $lat_{qt}$ denote latitudes in radians of the alter firms *i* and *j* at time *t* indirectly connected via a common broker firm; and $long_{pt}$ and $long_{qt}$ denote longitudes in radians of the alter firms *i* and *j* at time *t*. I averaged the distance obtained to calculate an aggregate measure of geographic distance at the ultimate parent level between alter firms *i* and *j* at time *t*. I then divided the measure by one thousand to obtain the final score in units of thousand miles.

***Broker-alter geographic distance (in thousand miles).*** I used the spherical law of cosines formula to calculate the great-circle distance between the broker firm's and each of the alter firms' subsidiaries or the firms themselves, whichever was directly involved in the alliance at time *t*. Next, I averaged these distances to obtain the distance between the broker firm and the first alter firm and the distance between the broker firm and the second alter firm. I then take the mean of these two distances and divide it by a thousand to obtain my ultimate measure of geographic distance between the broker and alter firms in thousand mile units.

***Different community.*** I used the community detection method proposed by Girvan and Newman (2002) and Newman and Girvan (2004) to detect communities and define modularity $M$ as $\sum_i (d_{ii}-\{d_{randomii}\})$ , where $d_{ii}$ is the fraction of ties within the $i^{th}$ community and $d_{randomii}$ is the expected fraction of ties within communities using another

network with the same number of communities and with the same tie distribution but with a random connection between nodes (firms). *M = 0* indicates that fraction of within-community ties in the observed network are not different from the expected fraction if the same quantity in a random network whereas *M = 1* suggests a strong community. I then use the Guimera and Amaral's (2005) simulated annealing optimization algorithm to find the partition of firms into communities such that *M* has the largest value. Recent studies have used the same approach to detect communities (e.g., Gulati, Sytch, & Tatarynowicz, 2012; Sytch et al., 2012; Tatarynowicz et al., 2016). Next, I code this measure as *1* if all the three members of the structural hole triad pertain to different communites and *0* otherwise.

**Control Variables**

***Alters' brokerage experience.*** I measure the sum of the number of brokerage triads spanned by the two alter firms before year *t* for *Alters' brokerage experience* because the structural hole spanning could enhance the ability of alter firms to identify brokerage relations. The alter firm's acquaintance with the existence of structural holes determines whether it would act to reduce the structural benefits reaped by the broker firm (Hahl et al., 2016). How the alter firm's managers create mental maps of actual networks affects the bargaining posture they adopt against the broker firm's managers (Krackhardt, 1987; 1990).

***Alter-alter past ties.*** I next control for *Alter-alter past ties* because alter firms might know one another because of their past alliances by aggregating all alliances

between the two alter firms of a structural hole triad before time *t* (Levin, Walter, & Murnighan, 2011). Not controlling for this variable might misattribute structural hole instability from past alliances to the geographic distance.

***Alter-alter knowledge difference.*** I capture *Alter-alter knowledge difference* until time *t* with the Jaccard coefficient (Yayavaram & Ahuja, 2008) using the formula $1-\frac{|\ Subclass_{alter1} \cap Subclass_{alter2}\ |}{|\ Subclass_{alter1} \cup Subclass_{alter2}\ |}$, where $Subclass_{alter1}$ and $Subclass_{alter2}$ are the unique pharmaceutical patent subclasses that each alter firm patented in until the observation year *t*.

***Alters' status difference.*** In year *t*, I next control for *Alters' status difference* in a triad using the differences in Bonacich centrality (normalized) (Bonacich, 1972).

***Broker's normalized degree.*** To proxy for the broker firm's influence in the overall network, which might influence the number of alternatives available to the broker and also its power over the alter firms, I use *Broker's normalized degree* centrality (Freeman, 1978). I next control for the number of structural holes spanned by the broker firm at time *t*.

***Broker's lack of constraint.*** I use the Burt's (1992) constraint measure with Zaheer and Bell's (2005) transformation for *Broker's lack of constraint*. This measure captures the autonomy the broker firm has in managing the relationship.

***Broker-alter past ties.*** This measure captures the strength or intensity of relationships between the broker and alter firm. Strong relationships engender trust

(Granovetter, 1973; Brass, Butterfield, & Skaggs, 1998), increasing the opportunity for the closing of the structural hole or at least less exploitation of surplus by the broker. First, I measure the number of past alliances between the broker and alter firm *1* and also the broker and alter firm *2* before time *t*. Second, I multiply both the values to calculate the effect of transitivity (Fleming, Mingo, & Chen, 2007).

***Broker-alter status difference.*** I account for the status difference between the broker firm and each of the alter firms in a triad, *Broker-alter status difference*, using the differences in normalized Bonacich centrality (Bonacich, 1972) and taking the mean of the two differences for the year *t*.

***Broker-alter knowledge difference.*** I measure *Broker-alter knowledge difference* using the Jaccard coefficient (Yayavaram & Ahuja, 2008)

$1-\frac{|\,Subclass_{broker} \cap (Subclass_{alter1} \cup Subclass_{alter2})\,|}{|\,Subclass_{broker} \cup (Subclass_{alter1} \cup Subclass_{alter2})\,|}$, where *Subclass* refers to the unique pharmaceutical subclasses in which each of the three broker and alter firms patented until time *t*.

***# of same country dyads.*** This variable takes a value of *3* if all the three members of the structural hole triad or their subsidiaries, whichever is directly responsible for the alliance, belong to the same country because when the triad's firms are in different countries, the effects of geography are likely to be stronger. Zero reflects all the members are located in different countries.

***# of same SIC dyads.*** This measure captures the influence of different sub-industries using this variable. It takes a maximum value of *3* when all the three members of the brokerage triad operate in the same 4-digit SIC codes, and *0* when none of them share the same sub-industry.

***Triad main component membership.*** For this variable, I assign a value of *1* to this dummy variable if all the three broker and alter firms belong to the main component of the network. Membership in the main component might make it easier for partners to collaborate and access information, reducing the likelihood of brokerage persistence (Dahlander & McFarland, 2013).

**Model Estimation**

I use discrete-time survival method for non-repeated events to empirically test my hypotheses (Allison, 1982). My event of interest, decay or "death" of the brokerage triad, is non-repeated in that it occurs only once over the life span of the brokerage triad. In case of non-repeated events, I do not need any correction for non-independence of observations for the same brokerage triad (D' Agostino, Lee, Belanger, Cupples, Anderson, & Kannel, 1990).

Although a continuous-time proportional hazards model could represent the underlying data generating process for my estimation sample, I do not have the exact dates of alliance termination but I do have exact years. In other words, although the survival time might be continuous, I observe it in (yearly) intervals. Also, for the same year, I have multiple terminations (Ryu, 1994). In such cases, discrete time survival

models are more appropriate than their continuous time counterparts (Allison, 2014). Under such circumstances, a complementary log-log discrete time survival model is identically equal to the continuous time Cox proportional hazards model (Allison, 1982). Also, this model is more robust to the choice of interval length whereas a logit model changes significantly with the selection of the interval, say triad-years versus triad-months, making the coefficients from different interval choices incomparable (Allison, 2010).

The complementary log-log model is preferred to logit or probit models in the case of events in which either failures (deaths) or successes (continuity) are rare (Powers & Xie, 2000). In other words, the model is suitable when the response variable, *y*, has a skewed distribution, with a high percentage of either *1*'s or *0*'s in the estimation sample (Cameron & Trivedi, 2010). My estimation sample has 85.57 percent decay cases (14,453 events). Thus, my data exhibits asymmetry. In contrast to the logit or probit models, the complementary log-log links are asymmetric in that, for $h_{jt}$ ($y = 1 \mid x$) = 0.5, the change in hazard when a covariate *x* increases by a given amount is different from the change when the covariate decreases by the same amount (Long, 1997).

In the complementary log-log model, $h_t$ ($y = 1 \mid x$) = F($X_{it}\beta$), F($X_{it}\beta$) is the cumulative distribution function of the extreme value distribution (Cameron & Trivedi, 2005). An extreme value distribution is the limiting (asymptotic) distribution for the maximum or the minimum of an extremely large number of random observations drawn from the same user-specified distribution. I estimate the hazard of brokerage instability

using the following complementary log-log regression model. $\log\{-\log(1-h_t)\} = \alpha_t + X_{it}\beta$, where $h_t$ refers to the hazard of brokerage decay at time $t$; $\alpha_t$ are the survival time period dummies; and $X_{it}$ is the set of independent variables including controls and a constant.

**Results**

Table 4 presents the descriptive statistics and the bivariate correlation matrix for explanatory variables and controls. The mean variance inflation factor (VIF) for the variables is 2.27, and none of the variables exceed the VIF limit of 10, suggesting no significant multicollinearity concerns (Belsey, Kuh, & Welsch, 1980). In Table 5, I present the results of the discrete time complementary log-log survival model. Model 1 is my baseline model with only control variables. Next, I add my main theoretical variables of interest in Models 2, 3, and 4, with Model 4 being my full model.

As predicted in H4a, I see in Model 4 of Table 5 that as the *Alter-alter geographic distance* increases by one standard deviation, the hazard of brokerage decay decreases by 9.31 percent (b = -0.04, $p$ = 0.00), keeping other variables constant. Likewise, consistent with H4b, a one standard deviation increase in the *Broker-alter geographic distance* decreases the hazard of decay by 8.85 percent (Model 4: b = -0.05, $p$ = 0.00), thus providing support for H4b, holding other variables constant at their respective values. Consistent with H5 about the brokerage triad's partners' locations in different communities, I find that the broker and alter firms' membership in different communities increases the hazard of decay by 8.42 percent (Model 4: b = 0.08, $p$ = 0.00).

**Robustness Checks**

My specification of the discrete-time survival model is equivalent to the Cox proportional hazard model. However, my results are robust to discrete-time equivalent of exponential, Gompertz, and Weibull models for continuous survival time data. I also ran a discrete-time survival regression using logistic regression and found similar results (results available upon request).

I further investigate whether my hypothesized effects change over time. I adopt two approaches. First, I interacted my independent variables with a continuous measure of the age of the brokerage (results available upon request). I do not find enough evidence to reject the null that the effects of *Alter-alter geographic distance* and the *Broker-alter geographic distance* do not vary over time (b = 0.00, $p = 0.31$; b = 0.00, $p = 0.66$), keeping other variables constant. This suggests that knowledge transfer across geographies remains an issue even with the passage of time. However, the effect of broker and alter firms' membership in different communities decreases by a factor of 0.97 for each unit increase in brokerage age. In other words, membership in different communities reduces the hazard of decay by 2.76 percent as the brokerage age increases by one year (b = -0.03, $p = 0.00$). It could be that with time, brokerage across different communities stabilizes due to the generation of trust between the alter firms and the broker firm.

Second, I interacted my independent variables with age dummies (results available upon request). In this case I do not find enough evidence to suggest that

brokerage across different communities stabilizes over time. Since I did not find consistent results across both the approaches, I did not include this interaction in my main model.

I further tested the robustness of my dependent variable using three alternate measures of decay. As shown in Figure 6, a brokerage triad can decay or become unstable (or end) in three different ways. First, in dissolution, either or both of the existing ties might dissolve. Second, bypassing the broker, the two alter firms might sever ties with it and form a tie between themselves leading to the broker's disintermediation. Lastly, the alter firms might connect with each other while maintaining their relationships with the broker, resulting in triadic closure.

I assign a value of *0* to the dummy *Dissolution* if the brokerage triad appeared for the first time for a particular year and for other consecutive years, if the relationships continue. The triad dissolves if the broker firm does not partner with either of the alter firms or vice versa. I operationalize *Dissolution* as *1* for the year in which the triad dissipates. I follow the brokerage triad over its life span and use a dummy code of *1* for *Disintermediation* to indicate whether the two alter firms connect while dissolving their tie with or cutting out the broker firm. Likewise, I use a dummy variable to capture the brokerage triad dissipation via *Closure* in which two unconnected alter firms connect while ties with the broker firm stays intact. *Closure* is coded as *1* for the year in which the two alter firms form a tie.

To test my hypotheses using these three alternative decay measures, I use discrete-time survival method for non-repeated events of multiple kinds (Allison, 1982). My event has multiple kinds in that the brokerage triad can decay via dissolution, disintermediation or closure. My estimation sample comprises of both high-frequency events (*Dissolution* – 83.97 percent) and rare events (*Disintermediation* – 0.57 percent; *Closure* – 1.03 percent). Logit models underestimate the probability of rare events (King & Zeng, 2001). Prior research has used complementary models in the context of extreme events, highly-frequent or rare (Coff, 2003; Barthélemy, 2017). Similar to my main model, I estimate the hazard of brokerage instability using the following complementary log-log regression model $\log\{-\log(1-h_{jt})\} = \alpha_t + X_{it}\beta$, where $h_{jt}$ refers to the three different hazards of brokerage triad dissolution, disintermediation and closure at time *t*.

The hazards of dissolution, disintermediation and closure are competing risks because the decay or death of brokerage triad because of any one type of event, for example by disintermediation, means that the triad is no longer at risk of other types of events such as closure, and vice versa. Similar to the continuous time survival models for competing risks, it is possible to use separate analyses for each type of termination (three in my case), treating the other types as censored, if we assume that censoring for other termination types occurs at the beginning of the year in which brokerage triads end (Allison, 1982; Jenkins, 2005). The maximum likelihood estimator thus generated is consistent and asymptotically normal (Anderson, 1980). Though it might not be as fully efficient as a multinomial logit estimator, the estimator consistently estimates the true

standard errors (Allison, 1982). Also, the presence of rare events might make the multinomial logit estimation difficult.

Table 6 shows the estimates of the discrete time complementary log-log survival model. As Model 5 indicates, a one standard deviation increase in the *Alter-alter geographic distance* decreases the hazard of brokerage triad *Dissolution* by 9.01 percent (b = -0.04, $p$ = 0.00), keeping other variables constant. Likewise, the hazard of disintermediation reduces by 21.72 percent (Model 6: b = -0.09, $p$ = 0.05) with a one standard deviation increase in the *Alter-alter geographic distance*. Similarly, as the *Alter-alter geographic distance* increases by one standard deviation, the hazard of brokerage triad closure reduces by 22.54 percent (Model 7: b = -0.10, $p$ = 0.01). Thus, the *Alter-alter geographic distance* significantly reduces the hazard of decay in all three operationalizations of the decay measure, namely dissolution, disintermediation, and closure. Overall, these results are consistent with my principal finding.

Next, as seen in Model 5, a one standard deviation increase in the *Broker-alter geographic distance* decreases the hazard of brokerage triad *Dissolution* by 8.26 percent (b = -0.05, $p$ = 0.00), holding other variables constant at their respective values. Similarly, I find that as the *Broker-alter geographic distance* increases by one standard deviation, the hazard of disintermediation reduces by 50.55 percent (Model 6: b = -0.39, $p$ = 0.00), also consistent with my main finding. However, the results from Model 7 do not provide enough evidence to reject the implied null hypothesis of no significant relationship between *Broker-alter geographic distance* and the risk of brokerage triad

closure although the (negative) sign is in the right direction (b = -0.05, $p$ = 0.33). Thus, the *Broker-alter geographic distance* significantly decreases the hazard of decay in all operationalizations except for *Closure* which has a negative but non-significant effect, mostly supporting my principal results.

Model 5 shows that the broker and alter firms' membership in different communities increases the hazard of brokerage triad *Dissolution* by 7.83 percent (b = 0.08, $p$ = 0.00), providing clear support for H5. Similarly, I find that *Different community* increases the hazard of brokerage disintermediation by 60.76 percent using two-sided 10% significance level, providing mild support for H5 (Model 6: b = 0.47, $p$ = 0.06). The results from Model 7 are not significant (b = 0.21, $p$ = 0.25), although the positive sign is in the hypothesized direction. Thus, the effect of location of triad members in different communities finds generally consistent support across the three operationalizations of the decay measure, with the postulated relationship supported for *Dissolution*, mildly supported for *Disintermediation*, and although the sign is in the right direction, not statistically significant for *Closure*. At the same time, I note that when I used the combined measure of decay in my main analysis, my results unambiguously support the hypothesis (H5), likely because the combined effects of dissolution and disintermediation are far stronger than those of closure.

As a further robustness test, I fit the three main models for *Dissolution*, *Disintermediation*, and *Closure* (Models 5, 6 and 7) simultaneously using the generalized structural equation estimator (Rabe-Hesketh, Skrondal, & Pickles, 2004). The model

assumes a common latent variable affecting all three dependent variables. I get virtually identical results as regards the direction and significance of the postulated effects (results on request).

One could argue that, in contrast to *Closure*, *Dissolution* and *Disintermediation* are similar in nature because in both the cases the broker firm is not in the picture and ties with respect to the broker does not exist. I re-estimate the discrete time complementary log-log survival model using a new dependent variable, *Death*, which takes a value of *1* in the event of either *Dissolution* or *Disintermediation.* My results hold (results not reported for brevity). As predicted in H4a, as the *Alter-alter geographic distance* increases by one standard deviation, the hazard of brokerage *Death* decreases by 9.14 percent (b = -0.04, $p$ = 0.00), keeping other variables constant. Likewise, a one standard deviation increase in the *Broker-alter geographic distance* decreases the hazard of decay by 8.78 percent (b = -0.05, $p$ = 0.00), thus providing further support for H4b, holding other variables constant at their respective values. In relation to the brokerage triad's partners' locations in different communities, I find that the broker and alter firms' membership in different communities increases the hazard of decay by 8.16 percent (b = 0.08, $p$ = 0.00), consistent with H5.

## SUMMARY

In this chapter I examine the evolution of brokerage, especially its persistence or its decay, by delving more deeply into the embeddedness of (brokerage) triad members in geographic, and also network, space. As hypothesized, my results show that geographic

distance, either between the alters, or between the broker and the alters, promotes the persistence of brokerage structures, thereby highlighting the importance of the spatial embeddedness of network ties. More to the point, when the network tie comprises of the flow of knowledge resources between alliance partners in a network, the role of distance matters greatly, given the sensitivity of the flows of information, particularly that of a tacit nature, across geographic distance.

Interestingly, my supplementary analyses breaking down the construct of brokerage decay show that for alter-alter distance, structural holes are least likely to terminate through closure or disintermediation but comparatively more likely to terminate through dissolution (even though the overall effect for dissolution is also negative). The findings suggest that greater distance between the alters imposes greater costs of tie formation between them, either for a disintermediating tie or a closure tie, thereby skewing the pattern of brokerage evolution away from direct alter ties and toward a breakdown of the tie. For broker-alter distance, termination through *disintermediation* is least likely, partially mirroring the results for alter-alter distance, but suggesting that when the true nature of brokerage is less accessible to the alters, alter firms also find it harder to find common ground with each other and form a direct disintermediating tie. However, they are comparatively likelier to terminate their tie with the broker through dissolution (even though the effect is negative, or less likely overall). Future research might examine the contingencies which govern when and why one form of brokerage termination is less frequent than another.

My hypothesis on the impact on persistence of the presence of the triad's members in the same or different network communities also found clean support. The results suggest that the location of the triad's members within the same community may attenuate the broker's self-seeking behavior, lowering the incentives for and the likelihood of brokerage decay. At the same time, when the triad's members are located in different network communities, inter-community competition and greater costs of spanning community boundaries limit the value from brokerage, prompting brokerage decay. Interestingly, in light of my first set of results on the enhanced stability of brokerage from geographic distance, these results might seem counter-intuitive if network communities are viewed as synonymous with geographic clusters. However, my results also highlight the essential distinction between network communities and geographic clusters, playing up the countervailing mechanisms that operate in networks to maintain stability. However, the mechanisms that promote persistence are quite different in geographic clusters.

Some research in economic geography hints at how and why the seemingly counterintuitive results might have come about. Ter Wal and Boschma (2009) suggest that the assumptions of the geographic cluster literature may not map onto networks because just by virtue of being in the same geographic cluster, firms are not necessary connected to one another, and therefore not in the same network community. Thus, when in the same geographic cluster, firms are only connected to one another through *unevenly* distributed networks. My results regarding the stability of brokerage in network

communities also supports recent work that brokers may not only be 'playing nice' when they are present in the same network community as their alters but through externalities may also be sharing the fruits of brokerage more broadly.

In my supplementary analyses splitting apart the decay construct into three component parts for the network community effects on stability I found, as expected, statistically significant results for *dissolution*, suggesting that brokerage termination was *more* likely when the triad's partners were located in different communities. The results regarding the greater likelihood of *disintermediation* when partners are located in different communities are weakly supported, suggesting that brokerage or triadic decay through alters connecting directly is hampered by the excessive costs of traversing community boundaries.

My study is not without limitations. I assume that the technological knowledge attributes do not change over time, or at least change only proportionately, and hence, the effect of geographic proximity on knowledge transfer is always along the same direction. To the extent that knowledge characteristics evolve differently over time and the effect of geographic distance is contingent on how these properties evolve, my conclusions could be weakened. In addition, it could be that my geographic distance construct is a crude measure of the underlying differences in time zones, differences in language and differences in countries. In this regard, future work could explore the black box of geographic distance. Nevertheless, to the extent that *# of same country dyads* controls for such differences, my hypothesized effects can be attributed to geographic distance.

**TABLE 4**

**Descriptive Statistics and Correlations[a]**

| | Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Decay | 1.00 | | | | | | | | | | | | | | | |
| 2 | Alters' brokerage experience | -0.01 | 1.00 | | | | | | | | | | | | | | |
| 3 | Alter-alter past ties | 0.00 | 0.14 | 1.00 | | | | | | | | | | | | | |
| 4 | Alter-alter knowledge difference | 0.00 | -0.34 | -0.08 | 1.00 | | | | | | | | | | | | |
| 5 | Alters-alter status difference | -0.01 | 0.69 | 0.05 | -0.11 | 1.00 | | | | | | | | | | | |
| 6 | Broker's normalized degree | -0.02 | -0.11 | -0.03 | 0.13 | -0.15 | 1.00 | | | | | | | | | | |
| 7 | Broker's lack of constraint | -0.00 | -0.21 | -0.05 | 0.20 | -0.18 | 0.73 | 1.00 | | | | | | | | | |
| 8 | Broker-alter past ties | -0.01 | 0.22 | 0.06 | -0.11 | 0.08 | 0.08 | 0.01 | 1.00 | | | | | | | | |
| 9 | Broker-alter status difference | -0.01 | -0.40 | -0.06 | 0.26 | -0.43 | 0.88 | 0.66 | 0.02 | 1.00 | | | | | | | |
| 10 | Broker-alter knowledge difference | 0.02 | -0.40 | -0.05 | 0.18 | -0.38 | -0.20 | -0.21 | -0.20 | 0.03 | 1.00 | | | | | | |
| 11 | # of same country dyads | 0.02 | 0.05 | 0.03 | -0.04 | -0.00 | 0.05 | 0.10 | 0.03 | 0.02 | 0.01 | 1.00 | | | | | |
| 12 | # of same SIC dyads | -0.00 | 0.06 | 0.02 | -0.10 | 0.03 | -0.13 | -0.10 | 0.03 | -0.16 | -0.08 | -0.03 | 1.00 | | | | |
| 13 | Triad main component membership | 0.01 | 0.03 | 0.00 | 0.06 | 0.06 | 0.09 | 0.18 | 0.02 | 0.07 | -0.02 | 0.04 | -0.01 | 1.00 | | | |
| 14 | Alter-alter geographic distance (in thousand miles) | -0.04 | -0.04 | -0.01 | 0.04 | -0.02 | 0.01 | 0.00 | 0.05 | 0.02 | -0.03 | -0.56 | 0.09 | -0.00 | 1.00 | | |
| 15 | Broker-alter geographic distance (in thousand miles) | -0.04 | 0.01 | -0.00 | -0.02 | 0.01 | 0.01 | -0.06 | 0.03 | 0.01 | -0.04 | -0.70 | 0.02 | -0.03 | 0.43 | 1.00 | |
| 16 | Different community | 0.01 | 0.12 | 0.02 | -0.16 | 0.05 | 0.11 | 0.11 | 0.03 | 0.02 | -0.19 | 0.04 | 0.03 | 0.03 | -0.03 | 0.01 | 1.00 |
| | Mean | 0.24 | 212.34 | 0.05 | 0.91 | 1.55 | 0.05 | 0.88 | 26.99 | 2.47 | 0.75 | 1.43 | 1.70 | 1.00 | 3.55 | 3.02 | 0.15 |
| | S.D. | 0.43 | 396.15 | 0.61 | 0.15 | 1.68 | 0.03 | 0.10 | 52.24 | 2.36 | 0.20 | 1.08 | 1.04 | 0.06 | 2.59 | 1.80 | 0.36 |
| | Min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | -5.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Max | 1.00 | 2,930.00 | 24.00 | 1.00 | 8.18 | 0.10 | 0.95 | 1,620.00 | 7.44 | 1.00 | 3.00 | 3.00 | 1.00 | 11.78 | 10.31 | 1.00 |

[a] The estimation sample is a 21-year (calendar time) unbalanced panel of 17,212 brokerage triads and 61,495 triad-year observations

## TABLE 5

**Estimation of the Hazard of Decay using Discrete-time Survival Model (Complementary Log–Log)[a]**

| Variables | Model 1: Controls | Model 2: Alter-alter distance | Model 3: Broker-alter distance | Model 4: Community |
|---|---|---|---|---|
| *Controls* | | | | |
| Alters' brokerage experience | -0.00 | -0.00 | -0.00 | -0.00 |
| | (-0.53) | (-0.61) | (-0.63) | (-0.71) |
| Alter-alter past ties | 0.02 | 0.02 | 0.02 | 0.02 |
| | (1.13) | (1.17) | (1.22) | (1.22) |
| Alter-alter knowledge difference | -0.13* | -0.12+ | -0.14* | -0.12+ |
| | (-2.07) | (-1.87) | (-2.31) | (-1.95) |
| Alters-alter status difference | 0.02** | 0.02** | 0.02* | 0.02** |
| | (2.86) | (2.66) | (2.56) | (2.72) |
| Broker's normalized degree | -8.19** | -8.08** | -7.62** | -7.88** |
| | (-8.39) | (-8.29) | (-7.84) | (-8.07) |
| Broker's lack of constraint | 0.65** | 0.73** | 0.70** | 0.68** |
| | (4.70) | (5.21) | (4.97) | (4.85) |
| Broker-alter past ties | -0.00 | 0.00 | 0.00 | 0.00 |
| | (-0.13) | (0.31) | (0.78) | (0.83) |
| Broker-alter status difference | 0.06** | 0.06** | 0.06** | 0.06** |
| | (5.63) | (5.41) | (5.14) | (5.35) |
| Broker-alter knowledge difference | 0.07 | 0.07 | 0.06 | 0.08 |
| | (1.29) | (1.25) | (1.17) | (1.49) |
| # of same country dyads | 0.04** | -0.02+ | -0.07** | -0.07** |
| | (4.74) | (-1.76) | (-6.33) | (-6.39) |
| # of same SIC dyads | 0.00 | 0.01 | 0.01 | 0.01 |
| | (0.02) | (0.93) | (0.79) | (0.73) |
| Triad main component membership | 0.12 | 0.14 | 0.15 | 0.14 |
| | (0.82) | (0.92) | (0.93) | (0.89) |
| *Independent variables* | | | | |
| Alter-alter geographic distance (in thousand miles) | | -0.04** | -0.04** | -0.04** |
| | | (-9.83) | (-9.41) | (-9.34) |
| Broker-alter geographic distance (in thousand miles) | | | -0.05** | -0.05** |
| | | | (-7.90) | (-7.98) |
| Different community | | | | 0.08** |
| | | | | (3.43) |
| *Other* | | | | |
| Intercept | -1.80** | -1.70** | -1.43** | -1.45** |
| | (-9.93) | (-9.13) | (-7.47) | (-7.56) |
| Observations | 61,490 | 61,490 | 61,490 | 61,490 |
| Survival time dummies | Yes | Yes | Yes | Yes |
| Log likelihood | -33,726 | -33,675 | -33,643 | -33,638 |

[a]Cluster-robust z-statistics in parentheses; two-tailed tests for all variables

** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

## TABLE 6

### Different Operationalizations of the Hazard of Decay Event

| Discrete-time survival model (complementary log–log)[a]: Variables | Model 5: Hazard of Dissolution | Model 6: Hazard of Disintermediation | Model 7: Hazard of Closing |
|---|---|---|---|
| *Controls* | | | |
| Alters' brokerage experience | -0.00 | 0.00 | -0.00 |
| | (-1.43) | (1.07) | (-0.27) |
| Alter-alter past ties | 0.02 | 0.05 | -0.22+ |
| | (1.49) | (0.88) | (-1.73) |
| Alter-alter knowledge difference | -0.04 | -1.53** | -2.33** |
| | (-0.57) | (-2.98) | (-7.59) |
| Alters-alter status difference | 0.03** | 0.05 | -0.07 |
| | (3.35) | (0.62) | (-1.49) |
| Broker's normalized degree | -8.46** | -19.63+ | 20.09* |
| | (-8.58) | (-1.75) | (2.31) |
| Broker's lack of constraint | 0.77** | -2.33* | -2.17** |
| | (5.37) | (-2.03) | (-2.72) |
| Broker-alter past ties | -0.00 | 0.00** | 0.00 |
| | (-0.04) | (5.19) | (0.47) |
| Broker-alter status difference | 0.07** | -0.07 | -0.45** |
| | (6.22) | (-0.59) | (-4.40) |
| Broker-alter knowledge difference | 0.12* | -4.12** | -2.40** |
| | (2.30) | (-7.17) | (-5.62) |
| # of same country dyads | -0.07** | -0.42** | -0.04 |
| | (-5.99) | (-3.90) | (-0.40) |
| # of same SIC dyads | 0.01 | -0.50** | -0.06 |
| | (1.25) | (-4.56) | (-0.71) |
| Triad main component membership | 0.08 | | |
| | (0.51) | | |
| *Independent variables* | | | |
| Alter-alter geographic distance (in thousand miles) | -0.04** | -0.09+ | -0.10** |
| | (-8.95) | (-1.95) | (-2.80) |
| Broker-alter geographic distance (in thousand miles) | -0.05** | -0.39** | -0.05 |
| | (-7.37) | (-5.92) | (-0.97) |
| Different community | 0.08** | 0.47+ | 0.21 |
| | (3.15) | (1.88) | (1.15) |
| *Other* | | | |
| Intercept | -1.63** | 2.75** | 0.38 |
| | (-8.51) | (2.69) | (0.43) |
| Observations | 61,490 | 60,695 | 60,217 |
| Survival time dummies | Yes | Yes | Yes |
| Log likelihood | -33,314 | -613.5 | -1,073 |

[a]Cluster-robust z-statistics in parentheses; two-tailed tests for all variables

** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

**FIGURE 4**

**Open Triad**

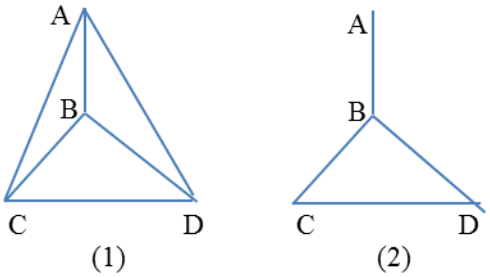



**FIGURE 5**

**Stable Triad**

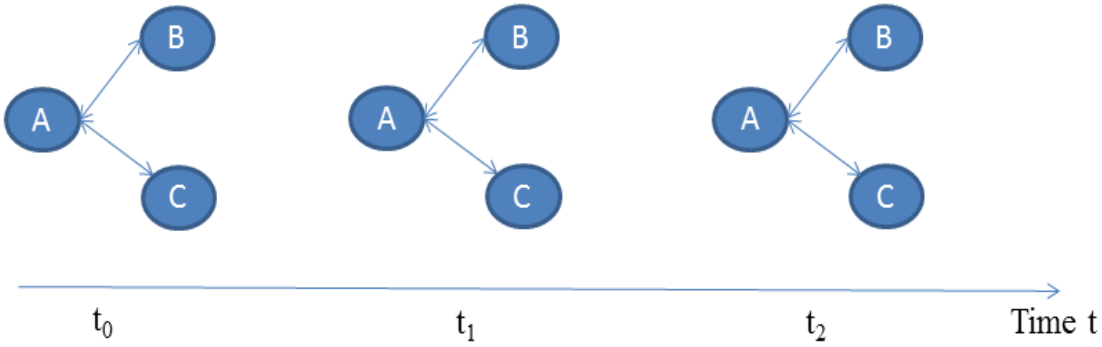
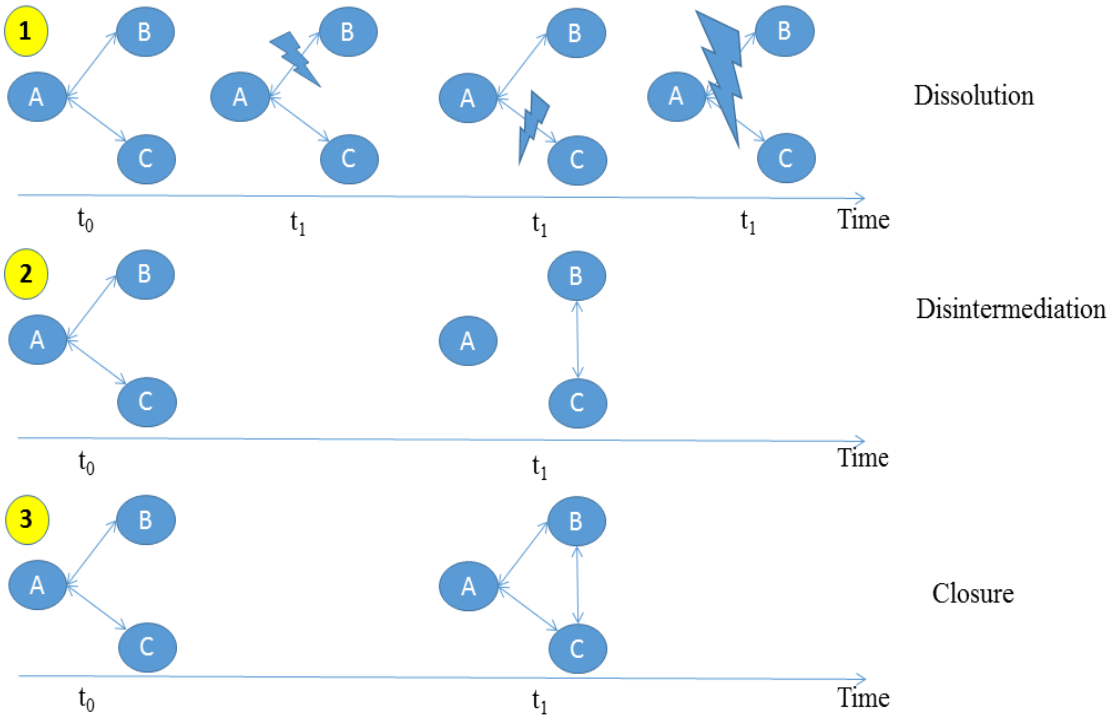


**FIGURE 6**

**Different Types of Decay Events**



# CHAPTER 4

## Conclusion

This dissertation focuses on first the consequences and second the antecedents of network stability. I find that ego-network stability negatively affects the focal firm's innovation performance because knowledge is more difficult to retrieve over time, because the focal firm faces relational lock-in, and because knowledge becomes redundant in stable networks, thus reducing the overall knowledge heterogeneity in the firm's network resources. Spanning structural holes mitigates this negative effect because holes allow the focal firm to access diversity and timely knowledge. In contrast, the focal firm's geographic concentration of inventive activities increases the negative effect of stability because of the lack of diversity in knowledge environments.

My work speaks to the extensive debate on the innovation value of network-structure configurations. Though most studies acknowledge that innovation benefits accrue from open network configurations, i.e., structural holes, both at the inter-firm level (e.g., Zaheer & Bell, 2005) and at the level of individuals (e.g., Tortoriello & Krackhardt, 2010), some studies have shown the contrary (e.g., Ahuja, 2000). In view of conflicting results, research has shifted focus to either conditioning variables (e.g., Tan, Zhang, & Wang, 2015) or hybrid positions that emphasize both structural holes and closure occurring together (e.g., Baum, van Liere, & Rowley, 2007) to better understand the relationship between structure and innovation performance. Yet, studies analyzing the structural determinants of innovation performance have focused mostly on the outcomes of variations in the configuration of network structures. In that case, not taking ego-

network stability into consideration might render empirical models that study the relationship between network structure and performance underspecified because stability may be acting as an unobserved variable.

The possibility that stable network structures can get stale and ossified raises an important question about its implications for network renewal and performance. As firms evolve their networks, what structures should be retained and what types need to be reconstituted in order to maintain the highest levels of ego-network performance? Further, the creation and deletion of network ties, particularly at the interfirm level, are hardly costless. In this regard, there clearly exists a trade-off between the cost of network change and its declining innovation value over time. Put another way, at the limit firms, in order to keep innovation high, may be spending too much in the process of changing network partners. At the same time, given that firms are known to get locked in with unproductive partners over time, and alliances may persist beyond their useful life (Inkpen & Ross, 2001), the challenge of dynamically maintaining an optimally innovative network presents both an empirical and a substantive opportunity. In sum, future research examining the dynamics of superior network performance would be worthwhile.

Another interesting area for future research would be to examine how ego-network stability, or the stability of a basic network building block, affects the stability of global network structures and properties such as small-worldliness, overall connectivity, and centrality. In other words, examining the link between local and global network stability may produce important insights if the effects are super-additive or substitutive.

In this regard, Palla, Barabási and Vicsek's (2007) work on the stability of network communities provides a useful exemplar, suggesting that the relationship between local and global stability varies with network size.

In this essay, controlling for knowledge-based and equity-based alliances, I assume that relevant knowledge for innovation might come from any type of alliance. Future studies could further refine our understanding of stability by classifying the network of relationships based on different activities in the alliance value chain such as upstream (e.g., research) relationships and downstream (commercialization) relationships (Stuart, Ozdemir, & Ding, 2007). Research could investigate, for example, if the innovation effects of stability are the same for these classifications or would a mix of "unstable" upstream and "stable" downstream ego-network relationships provide the best recipe for innovation?

In the follow-up essay of my dissertation, I study the origins of stability by examining the evolution of brokerage, especially its persistence or its decay, by delving more deeply into the embeddedness of (brokerage) triad members in geographic, and also network, space. My study elucidates how spatial and community embeddedness at the macro level influences firms' behavior at the micro nodal level, affecting the persistence of brokerage structures. In addition, my focus on the triad for theoretical exposition underscores the role of collective agency in the context of network longevity and reorganization. Embeddedness, both geographic and social, may heterogeneously affect the individual agency of different members in the triad members as regards the continuity, or lack thereof, of brokerage. The net effect of these individual agencies and

their interactions determines the life expectancy of existing brokerage structures. Given that brokerage structures have been shown to exert such significant effects in alliance networks, my study becomes salient from both theoretical and empirical perspectives.

I extend recent work on network dynamics by studying the end of brokerage. Though we know much about network formation (e.g., Gulati & Gargiulo, 1999; Zaheer & Soda, 2009), little is known about the mechanisms underlying the persistence, and subsequent termination of, network structures. My emphasis on network structure termination derives from my belief that, though termination and genesis may seem different as they pertain to different stages in the life cycle of a network structure, both could actually be two sides of the same coin. Specifically, knowledge of both yields a rich picture of network reorganization and change. For example, brokerage decay through disintermediation or closure that results in the ending of a brokerage structure also marks the genesis of a new tie between network members, implying thereby the need for a more holistic study of network reorganization and evolution. Similarly, if we take a Penrosian view of network relationships as evolving in response to endogenous resource creation by firms in alliances, then structural hole dissolution might result in a new tie formation with firms outside of the existing brokerage triad, catalyzing network change. Thus, my research on brokerage termination is relevant for a more complete understanding of the genesis, and evolution, of networks.

My theorizing about stability also adds critical nuance to the research on strategic alliances. This study suggests that the fundamental unit to understand alliance learning and management may be the ego network or triad and not the dyad, providing support for

recent work that views alliances as a portfolio (Lavie, 2007; Vasudeva & Anand, 2011). Learning under such circumstances is not merely a function of dyadic alliance experience (Hoang & Rothaermel, 2005) but entails managing possibly conflicting relationship within the wider alliance portfolio. In addition, alliance research could take into consideration the stability of the portfolio of relationships (Bakker & Knoben, 2015) to understand how the focal firm may enhance its knowledge rents. Alliance governance likely has to be related to network governance, especially when it comes to the selection, monitoring and termination of structures over time.

My research also highlights the limitations of dyadic analyses in capturing the complexities of relational stability. Much of the scholarly work investigating stability and dissolution at the network level has looked into the benefits of having common third party ties or structural embeddedness (e.g., Gulati & Gargiulo, 1999). The presence of a common third party aids in maintaining order in the network relationship via social sanctions. However, extant work provides little theoretical insight into the situation when the common third party is a broker firm that is willing to withhold information and take sides for individual profit maximization. Opportunities and constraints available to the broker and alter firms jointly influence network reorganization and change and might not always be additive. In sum, in addition to existing theorizing about the "shadow of the future" (Axelrod, 1984) and the "shadow of others" (Polidoro, Ahuja, & Mitchell, 2011) emphasizing structural embeddedness in the persistence of network structures, I highlight the distinct influence of the "shadow of the broker."

My research may also inform practitioners in industry. Managers seeking innovation using interfirm alliances need to pay attention to both alliance network configuration and network stability. In situations which necessitate open-ended alliance relationships, or in uncertain situations in which firms cannot foresee alliance terminations in the near future, managers might improve their firms' innovation performance by spanning more structural holes. In sum, rewiring and refreshing the network configuration is the recommended course of action. However, when network stability looms large due to alliance persistence compulsions or other reasons, geographic dispersion and open structures limit its ill effects. In addition, managers are better off when they also pay attention to the geographic distance between alliance partners.

**Limitations and Future Directions**

Although the empirical context for my dissertation is the biopharmaceutical industry, I believe that my results are likely to hold in other industries with similar features such as the salience of innovation. Where the importance of innovation is less critical, or where alliances are used for purposes other than innovation, network stability may not produce negative effects on innovation. A further potential arena for generalizability may be to assess whether and when ego-network stability affects innovation at the level of individual scientists. In addition, a promising avenue for future studies is to examine the antecedents of overall ego-network stability, given its implications for performance (e.g., Sasovova et al., 2010). Overall, this study provides rich prospects for future research.

As regards network dynamics, questions to investigate with future work are: Are

alter firms empirically at a disadvantageous position vis-à-vis the broker firm in terms of returns, or even innovation? Does that disadvantage attenuate post decay? What are the contingencies in which one manifestation of decay gains prominence over the other? For example, under what conditions will a disintermediation strategy trump a closure strategy in terms of knowledge gains for the alter firms? Another area worthy of future scholarship is a mixed-level study with both a dyadic and a network focus and investigate if results differ at different levels of analysis.

Extant studies either ignore stability or assume a homogeneous distribution of stability among structural holes, typically that structural holes are transient and quick to decay (Burt, 1992: Stovel et al., 2011). I study differences in structural hole stability as a useful point of departure to theoretically enrich the discussion about the stability dimension of social capital and its consequences. One future avenue of research in this domain would be to dig deeper into the broker firm's motivation and its effect on stability.

Burt's theory of structural holes treats broker motivation and brokerage opportunity generated from the structural hole "as one and the same" and views the motivation question as a "nonissue" (Burt, 1992: 35). In contrast, one could argue that broker motivation is relevant because the firm has to decide whether to exploit the information and control benefits provided by the structural hole or forego some of these benefits in favor of pursuing more reciprocally-beneficial relationships with alter firms, which might lower the incentives for alter firms to close the hole, but possibly be perceived as benefiting the broker firm in the long run.

Framed in Burt's terms, the focal firm can adopt one of two logics of action while spanning a structural hole: in contrast to Burt's *tertius gaudens* logic, or "the third who enjoys," there could be an alternative brokerage logic: *tertius coordinans* or "the third who coordinates." In other words, *how* the focal firm acts as a broker might have implications for brokerage stability.

***The tertius coordinans rationale.*** While others, such as Obstfeld (2005), have also suggested alternatives to *tertius gaudens*, such as *tertius iungens*, it is important to recognize that in a *tertius iungens* setting the broker essentially brings together the two disconnected alters. My suggestion (for future work) of *tertius coordinans* differs from both *tertius iungens* and *tertius gaudens* in that unlike *iungens* the broker keeps the two alters apart, but unlike *gaudens* the broker coordinates between the alters rather than exploiting or controlling them. Thus, the *tertius coordinans* logic represents an "honest" broker that stays "passive" despite the two alter firms not connecting directly with each other. Burt (1992: 34) actually makes a reference to this kind of broker as the "passive player" who is interested in information but not control benefits, simply coordinating information or knowledge flow across alters (also see Spiro, Acton, & Butts, 2013). Put another way, the active, controlling broker, even in Burt's original theorizing, is but one manifestation of brokerage, although prominent in the current literature. The broker, on its part, might benefit through coordination by acting as a channel for knowledge exchange, and by recombining the knowledge acquired from the two alters. Over time, a high level of trust builds among the broker and alter firms, which reduces negotiation and knowledge transfer costs. Agreements are reached more easily and parties can more

readily have a "meeting of the minds." Moreover, trust decreases the propensity to defend against opportunistic behavior thereby promoting a more stable, long-term view on the part of all the members of the brokerage triad (Bromiley & Cummings, 1995).

More specifically, such a longer-term brokerage orientation implies that some brokers may believe that their self-interest is better served by a more reciprocal and equitable knowledge sharing and coordination approach. This logic is akin to the work of economist Ernst Fehr and his colleagues, from which I quote below:

> A long-standing tradition in economics views human beings as exclusively self-interested. In most economic accounts of individual behavior and aggregate social phenomena, the "vast forces of greed" (Arrow, 1980) are put at the center of the explanation. In economic models human actors are typically portrayed as "self-interest seeking with guile (which) includes . . . more blatant forms, such as lying, stealing, and cheating ... (but) more often involves subtle forms of deceit" (Williamson, 1985: 47). However, as we will document below, many people deviate from purely self- interested behavior in a reciprocal manner. Reciprocity means that in response to friendly actions, people are frequently much nicer and much more cooperative than predicted by the self-interest model…There is considerable evidence that a substantial fraction of people behave according to this dictum (Fehr & Gachter, 2000: 159).

Such reciprocity characterizes the "honest broker" and the subsequent trust that develops between the broker and the alters enables the structural hole to be stable and persist over time. In this respect, I am not assuming that the broker is "selfless" – rather I am assuming that the range of broker behaviors might extend beyond the consistent self-interested exploitation of the brokerage position. Furthermore, I am not implying that all brokers behave in a reciprocal fashion; just that because some significant proportion does, we are likely to see variation in the stability of the brokerage triad.

On the other hand, in the case of *tertius gaudens*, power asymmetries in the triad

make conflict or competition for the brokerage position imminent. In such situations, alter firms may attempt to replicate the structural advantages of the broker, severely straining the stability of structural holes (Buskens & van de Rijt, 2008) and making the brokerage structure transient. Also, the broker firm, while engendering competition among alters, might make the two alter firms aware of their combined bargaining power against it, eliminating the rents from brokerage. In sum, the coordinative nature of brokerage in *tertius coordinans* might increase the stability of the hole in contrast to the exploitative orientation in *tertius gaudens* (Simmel, 1950). Thus, because brokerage motivations might differ from one brokerage triad to the other, future research might look into how variations in the motivation of brokers affect stability.

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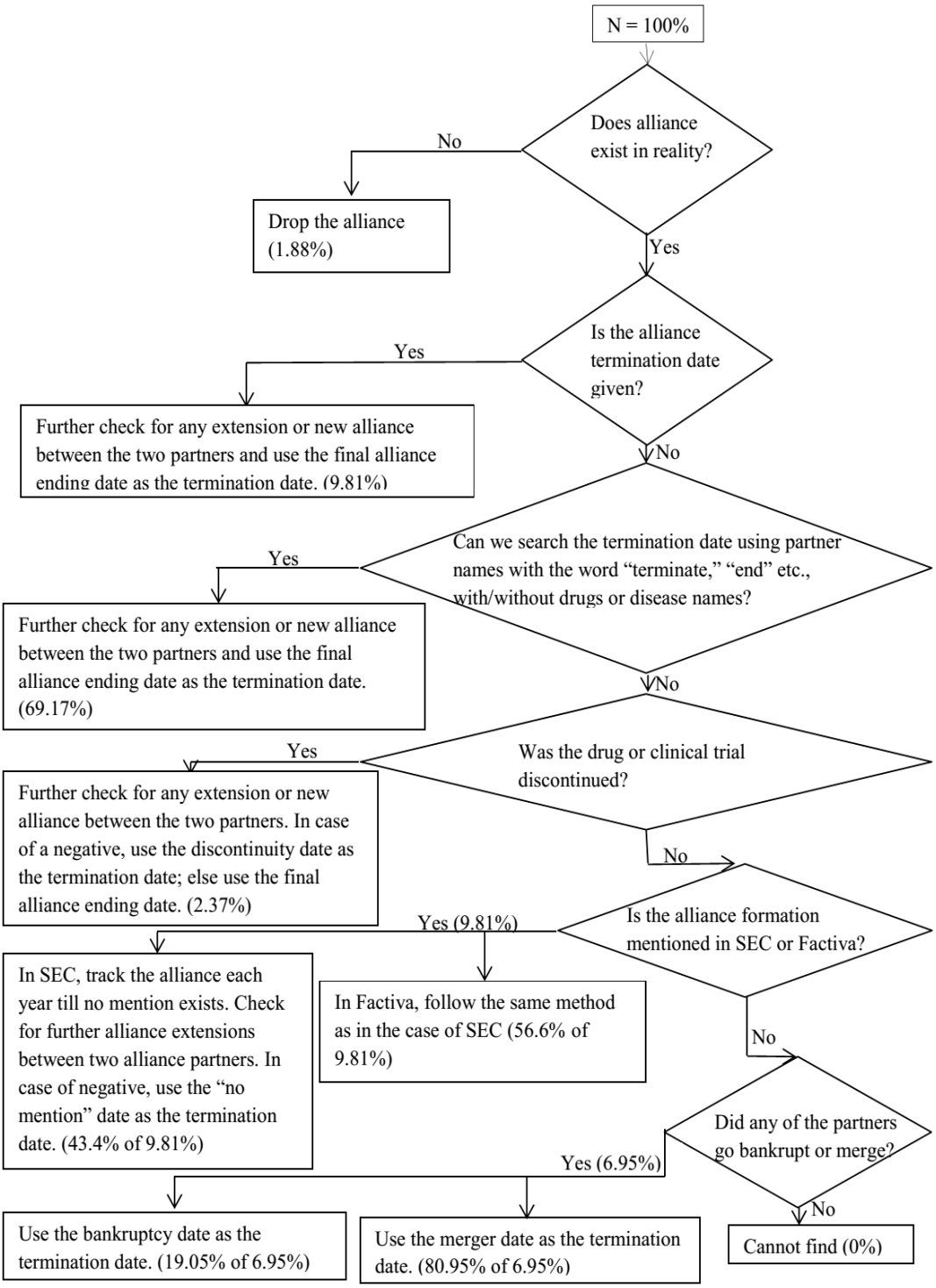
## APPENDIX 1
### Flowchart to Determine Alliance Duration



## APPENDIX 2

### Exemplars for Each Step in the Flowchart

### STEP 1: DOES THE ALLIANCE EXIST IN REALITY? THREE EXEMPLARS (CASES) OF ALLIANCES THAT I DROPPED (1.88%)

**Case 1: Advanced Magnetics, Inc., and Matritech, Inc. [01Aug1991]**

"Advanced Magnetics signed an agreement with Matritech to distribute jointly developed cell death detection products." - *SDC*

My conclusion: The alliance might not exist. I could not find any news or description pertaining to this alliance. The 10-K and 10-Q reports of Matritech, Inc., are available at http://www.getfilings.com/comp/k0000884847.html from 1996 to 2005. None of these documents discuss the alliance of 1991 or mention Advanced Magnetics, Inc., in a new alliance. Likewise, I know that Advanced Magnetics, Inc. (NASDAQ: AMAG) changed its name to AMAG Pharmaceuticals, Inc., in 2007 (https://www.amagpharma.com/ ) but again no information about the alliance exist.

**Case 2: Green Cross, Corp., and Oxford Virology, Ltd., (Oxford Virology, P.L.C.) [01Jun1990]**

"Green Cross Corp signed an agreement with Oxford Virology Ltd to market their vaccine Hepavax." - *SDC*

My conclusion: The alliance might not exist. I could not find any news or description pertaining to this alliance. Furthermore, Oxford Virology, P.L.C., which was incorporated on 20 April 1989 is dissolved with latest accounts filed only till 30 Sep 1990. Next filing of accounts was due on 30 Jun 1992 but was not filed according to https://companycheck.co.uk/company/02374305/OXFORD-VIROLOGY-PLC/companies-house-data. Given that the alliance was announced on 01 Jun 1990 but no news exist, and Oxford was dissolved with a year or so with last account filing till 30 Sep 1990, I cannot conclude that the alliance exist in reality.

**Case 3: HBT Holland Biotechnology, B.V., and Diagnostica Stago, S.A.S. [01Jan1991]**

"HBT Holland biotechnology B.V. signed an agreement with Diagnostica Stago for Diagnostica to distribute Hbt's IFN-related products in the German market." - *SDC*

My conclusion: The alliance might not exist. I could not find any news or description pertaining to this alliance. HBT Holland Biotechnology, B.V., is located in Leiden in the Netherlands and Diagnostica Stago in Cedex, France. Even local searches such as those using google.fr and google.nl yielded no results.

**STEP 2: IS THE ALLIANCE TERMINATION DATE GIVEN? CHECK FOR ANY EXTENSION OR NEW ALLIANCE BETWEEN THE TWO PARTNERS AND USE THE FINAL ALLIANCE ENDING DATE AS THE TERMINATION DATE. THREE EXEMPLARS (CASES) (TERMINATION DATES FOUND IN 9.81% OF THE CASES)**

**Case 1: Axcan Pharma, Inc., and Grupo Ferrer Internacional, S.A. [20 Jul 2000]**

"Axcan Pharma (AP) and Grupo Ferrer International (GF) planned to form a strategic alliance wherein AP sublicensed to GF the rights to distribute *PHOTOFRIN* in Spain, Portugal, Greece as well as in all Central and South America countries (original length = 5 years)" (emphasis mine). - *SDC*

https://www.thefreelibrary.com/Axcan+and+Grupo+Ferrer+to+form+Strategic+Alliance+for+the...-a063583153
"Axcan and Grupo Ferrer to form Strategic Alliance for the Distribution of Photofrin in Europe, Central and South America.
MONT SAINT-HILAIRE, Quebec, July 20 /CNW-PRN/ -
…Under the terms of the proposed agreement expected to be executed in October 2000, Grupo Ferrer will assume responsibility for completing the registration of *PHOTOFRIN(R)* in all countries that are part of its exclusive territory. Axcan will also benefit from a right of first refusal granted for a *five-year period* with respect to the distribution of a gastro-intestinal product developed or acquired by Grupo Ferrer in Canada and the United States. Other terms were not disclosed..." (emphasis mine).

My conclusion: I reconfirm that the alliance existed in reality and its original length was five years.

http://www.secinfo.com/dVut2.25Hk.d.htm
"Axcan Pharma Inc – '40-F/A' for 9/30/02 – EX-1
In January 2002, Axcan entered into a sublicense agreement for a *10-year period* with Grupo Ferrer International, S.A. ("Grupo Ferrer"), a Spanish company based in Barcelona, for the distribution of PHOTOFRIN in Spain, Portugal and Greece" (emphasis mine).

My conclusion: I further checked for any extension or new alliance and find that the relationship between Axcan and Grupo Ferrer was further extended from a five-year duration to a ten-year duration in 2002. Thus, the alliance existed at least till 2005, my last period of observation. I further validated that these parties did not terminate this alliance till 2005 because no such news exist.

**Case 2: Discovery Partners International, Inc., and Pfizer, Inc. [20 Dec 2001]**

"Discovery Partners International Inc(DO) and Pfizer Inc(PI) planned to form a strategic alliance to manufacture and develop libraries of high purity chemical compounds to be used in PI's drug discovery programs in the United States. The estimated potential value of this 4-year collaboration was to reach $95 mil US. Financial terms were not disclosed (original length = 4 years)." - *SDC*

http://www.thepharmaletter.com/article/discovery-partners-int-expands-pfizer-deal
"Discovery Partners Int expands Pfizer deal
01-03-2004
Discovery Partners International has signed a multi-year strategic chemistry agreement with drug major Pfizer, expanding the scope of their current collaboration which was initiated in December 2001…, the company expects at least $43-$46 million from Pfizer over the *next two* years" (emphasis mine).

My conclusion: I reconfirm that the alliance existed in reality in 2001 and existed at least till 2006 because the news is from 2004 and Discovery Partners expects payment from Pfizer over the next two years.

http://www.prnewswire.com/news-releases/discovery-partners-international-announces-termination-of-new-collaboration-discussions-with-pfizer-inc-and-consolidation-of-chemistry-operations-55733102.html
"Discovery Partners International Announces Termination of New Collaboration Discussions With Pfizer Inc and Consolidation of Chemistry Operations
Nov 29, 2005, 00:00 ET from Discovery Partners International, Inc.
SAN DIEGO, Nov. 29 /PRNewswire-FirstCall/ -- Discovery Partners International, Inc. (Nasdaq: DPII) announced today that the Company and Pfizer Inc have *terminated* discussions regarding a potential new collaboration to replace the Company's existing agreement with Pfizer that expires on *January 5, 2006*" (emphasis mine).

My conclusion: I further verified and found that the relationship was terminated on January 5, 2006.

**Case 3: Corixa, Corp., and GlaxoSmithKline Biologicals, S.A. [26 Jul 2004]**

"Corixa Corp (CC) and GlaxoSmithKline Biologicals (GB), a unit of GlaxoSmithKline PLC, formed an 8-year strategic alliance to manufacture as well as wholesale and supply adjuvant, monophosphoryl lipid A or MPL(R).;CC's MPL adjuvant, a component in GB's novel, proprietary adjuvant systems used in the development of future vaccines currently undergoing clinical trials or awaiting regulatory approval. Under terms of the agreement, CC agreed to expand cGMP compliant MPL production capacity in association with anticipated approvals of GB vaccines that contain MPL adjuvant (original length = 8 years)." - *SDC*

www.outsourcing-pharma.com/Preclinical-Research/GSK-acquires-Corixa-for-233m
"GSK acquires Corixa for €233m
May 2, 2005
GlaxoSmithKline has announced plans to acquire the Corixa Corporation..."

My conclusion: Even though SDC shows that the alliance duration is eight years or till 2012, I find that the alliance ended in 2005 because GlaxoSmithKline acquired Corixa on 12 July 2005.

**STEP 3: CAN WE SEARCH THE TERMINATION DATE USING PARTNER NAMES WITH THE WORD "TERMINATE," "END" ETC., WITH/WITHOUT DRUGS OR DISEASE NAMES? FURTHER CHECK FOR ANY EXTENSION OR NEW ALLIANCE BETWEEN THE TWO PARTNERS AND USE THE FINAL ALLIANCE ENDING DATE AS THE TERMINATION DATE. SEVEN EXEMPLARS (CASES) (TERMINATION DATES FOUND FOR 69.17% OF THE CASES)**

**Case 1: Incara Pharmaceuticals, Corp., and Elan Corp, P.L.C. [28 Dec 2000]**

"Incara Pharmaceuticals Corp (IP) and Elan Corp PLC(EC) completed their joint venture. In December 2000, IP and EC announced plans to form a joint venture named Incara Development Ltd to develop Herparin products using EC's medipad delivery system for treatment of inflammatory bowel disease. ID was to be owned 80% by IP, with EC owning the remaining 20% with an option to own 50% within the next six years. As part of the agreement, EC was to make a $4 mil US investment in IC." - *SDC*

https://www.sec.gov/Archives/edgar/data/1261734/000119312504138007/d424b3.htm
"Aeolus Pharmaceuticals, Inc.
(f/k/a Incara Pharmaceuticals Corporation)

Prospectus Supplement No. 5 dated August 11, 2004
(To Prospectus dated May 27, 2004)
In January 2001,…, Elan and the Company formed a Bermuda corporation, Incara Development, Ltd., to develop deligoparin,...In September 2002, Incara Development ended its Phase 2/3 clinical trial and the development of deligoparin due to an analysis of the clinical trial results, which showed that treatment with deligoparin did not meet the primary or secondary endpoints of the study. The results of the trial did not justify further development of deligoparin for treatment of ulcerative colitis and the development of deligoparin was terminated. Elan and the Company *ended* their collaboration in the joint venture in *November 2003* and the Company became the sole owner of Incara Development" (emphasis mine).

My conclusion: Even though the two partners formed a joint venture, which are supposed to be relatively stable, I find this partnership lasted only three years till November 2003.

https://www.sec.gov/Archives/edgar/data/1261734/000095016204000670/0000950162-04-000670.txt

"CONFORMED SUBMISSION TYPE: SC 13D/A
FILED AS OF DATE: 20040527
COMPANY CONFORMED NAME: INCARA PHARMACEUTICALS CORP
FILED BY:
COMPANY CONFORMED NAME: ELAN INTERNATIONAL SERVICES LTD
13. *Termination* Agreement, made the *19th day of November, 2003* (filed herewith)" (emphasis mine).

My conclusion: Incara and Elan terminated their partnership on 19 Nov 2003. I further find no new relationships were formed between the two parties.

http://adisinsight.springer.com/drugs/800006120
"Most Recent Events
OP2000
17 Sep 2002 Discontinued - Phase-III for Ulcerative colitis in USA (SC)
29 Aug 2002 Incara has completed patient enrolment in its phase II/III trial of deligoparin for the treatment of ulcerative colitis
20 Mar 2002 A study has been added to the Inflammatory Bowel Disorders therapeutic trials section"

My conclusion: I don't need this information because I already determined the

termination date. Note that Incara's drug was discontinued on 17 Sep 2002 and the alliance terminated by next year. Thus, drug discontinuity date is a close proxy for determining alliance duration, though not a focus of this section.

**Case 2: Eisai, Inc., and Pfizer, Inc. [25 Jul 2002]**

"Eisai Inc, a unit of Eisai Co Ltd, and Pfizer Inc formed a strategic alliance to manufacture and market *Cerebyx*, used for the treatment of epilepsy. Financial terms were not disclosed" (emphasis mine). - *SDC*

http://www.prnewswire.com/news-releases/eisai-inc-assumes-us-distribution-responsibilities-for-aciphexr-58749807.html
"*Jan 07, 2004*, 00:00 ET from Eisai Inc.
…*Last year*, Eisai acquired exclusive U.S. rights to promote Pfizer's *Cerebyx(R)* (fosphenytoin sodium injection)" (emphasis mine).

My conclusion: Eisai and Pfizer were partners at least till 2003.

http://www.eisai.com/pdf/eir/emat/4523_070515e.pdf
"*FY2006*
Financial Results
Presentation
May 15, 2007
Eisai Co., Ltd.
Expanded product portfolio:
…5. Cerebyx
® (Status epilepticus control agent)" (emphasis mine).

My conclusion: Eisai and Pfizer were partners at least till 2005, my last year of observation because Esai still has Cerebyx in its portfolio in 2006.

**Case 3: Sonus Pharmaceuticals, Inc., and Sicor, Inc. [01Jul 2002]**

"Sonus Pharmaceuticals Inc (SP) and Gensia Sicor Pharmaceuticals Inc formed a strategic alliance to manufacture and supply SP's *TOCOSOL(TM) Paclitaxel* to support advanced clinical development of cancer therapy product in the United States" (emphasis mine). - *SDC*

http://ir.oncogenex.com/releasedetail.cfm?ReleaseID=265742
"July 1, 2002

Sonus Pharmaceuticals Announces *TOCOSOL Paclitaxel* Manufacturing and Supply Agreement with Gensia Sicor Pharmaceuticals" (emphasis mine).

https://www.sec.gov/Archives/edgar/data/949858/000089256903002113/a92469b3e424b3.htm
"SONUS PHARMACEUTICALS, INC.
PROSPECTUS
*August 28, 2003*
SICOR Pharmaceuticals, Inc. is our primary manufacturer of *TOCOSOL Paclitaxel* for clinical studies and has also agreed to manufacture TOCOSOL Paclitaxel for commercialization" (emphasis mine).

My conclusion: Sonus and Sicor were partners at least till 2003.

http://files.shareholder.com/downloads/SNUS/0x0xS1104659-07-19876/949858/filing.pdf
"FORM 10-K
SONUS PHARMACEUTICALS INC
(Annual Report)
Filed 3/16/2007 For Period Ending 12/31/2006
In mid-2002, we entered into a manufacturing and supply agreement with Sicor Pharmaceutical Sales, Inc. (*Sicor is now known as TEVA Pharmaceuticals USA*). During 2003, in collaboration with *TEVA* Pharmaceuticals USA, we completed scale-up of …
" MSA " means the Manufacturing and Supply Agreement between Sonus and Gensia Sicor Pharmaceutical Sales, Inc. (now known as Sicor Pharmaceuticals, Inc.), effective as of June 26, 2002.
" Quality Agreement " means the Quality Agreement for the Manufacturing and Supply of *Tocosol*® Paclitaxel Injectable Emulsion between Sonus and Sicor Pharmaceuticals, Inc., effective as of *February 1, 2005*. A complete copy of the Quality Agreement is attached hereto as Exhibit A" (emphasis mine).

My conclusion: Sonus and Sicor were partners at least till 2005. Note that Sicor was acquired by Teva in 2004 (from my research on acquisitions). Hence, from 2002 to 2004 Sonus and Sicor were partners, and from 2004 to 2005 Sonus and Teva were partners.

**Case 4: Human Genome Sciences, Inc., and Genentech, Inc. [20 Apr 1994]**

"Human Genome Sciences Inc entered into a strategic alliance with Genentech Inc, a unit of Roche Holding, in which Human Genome Sciences granted Genentech an exclusive license to its Heart/Lung Selective DNase gene and recombinant DNA products derived

from the gene. Genentech intended to use the gene in the development of a treatment for cystic fibrosis. Financial terms were not disclosed." - *SDC*

"HD Human Genome Sciences and Genentech to collaborate
WC 271 words
PD 20 April 1994
SN Business Wire
SC BWR
LA English
CY (Copyright (c) 1994, Business Wire)
LP
ROCKVILLE, Md.--(BUSINESS WIRE)--April 20, 1994--Human Genome Sciences Inc. (HGS) (NASDAQ:HGSI) announced Wednesday that it has granted Genentech Inc. (NYSE:GNE) an exclusive option to license its recently discovered human Heart/Lung Selective DNase *(HL-DNase*) gene and recombinant DNA products derived from the gene" (emphasis mine). - *Factiva*

"HD Genentech Terminates HL-DNase Pact With Human Genome Sciences
WC 83 words
PD *3 March 1995*
ET 04:09 PM GMT
SN Dow Jones News Service
SC DJ
LA English
CY (Copyright (c) 1995, Dow Jones & Co., Inc.)
LP
ROCKVILLE, Md. -DJ- Human Genome Sciences Inc. (HGSI) said Genentech Inc. (GNE) *terminated* its previously announced option and evaluation agreement with Human Genome for heart-lung selective *human HL-DNase*.
TD
Genentech found the protein difficult to express in the systems used, Human Genome said.
(END) DOW JONES NEWS 03-03-95" (emphasis mine). - *Factiva*

My conclusion: Human Genome and Genentech terminated the relationship on 3 March 1995.

**Case 5: Ciba-Geigy, A.G., and CoCensys, Inc. [17 May1994]**

"Ciby-Geigy AG and CoCensys Inc have agreed to jointly develop in the US a therapeutic for the treatment of strokes and head trauma. The jointly developed drug was known as Acea 1021. Under the terms of the agreement, Ciba agreed to make an initial investment in CoCensys, with additional payments to be made in the future. In return, Ciba received the right to develop and market *Acea 1021* outside the US. Ciba was also slated to take an equity stake in CoCensys. CoCensys also entered into a marketing agreement with Ciba-Geigy Corp, Ciba's unit in Summit, New Jersey, at the same time as this agreement" (emphasis mine). - *SDC*

http://www.biocentury.com/biotech-pharma-news/strategy/1997-05-05/noteworthy-how-cocensys-plans-life-after-novartis-a4
"How CoCensys plans life after Novartis
By Ilan Zipkin
Staff Writer
Published on Monday, *May 5, 1997*
Finding opportunity in adversity is critical to running a sustainable company. CoCensys Inc. (COCN, Irvine, Calif.) is trying to do just that *after partner Novartis Pharma AG* (Basel, Switzerland) said it would *drop development of COCN's ACEA 1021 NMDA*-receptor antagonist for stroke and head injury. …The compound was originally licensed to Ciba-Geigy (now part of Novartis) in 1994 from Acea Pharmaceuticals Inc., at the same time that COCN acquired Acea and the rights to 1021 (see BioCentury May 23, 1994)" (emphasis mine).

My conclusion: CoCensys and Ciba-Geigy partnership lasted till 1995. In 1996 Ciba-Geigy and Sandoz formed Novartis (my research on acquisitions).Cocensys and Novartis alliance continued from 1996 to 1997. Note Novartis terminated the alliance after the merger.

**Case 6 Yamanouchi Pharmaceutical Co., Ltd., and Warner-Lambert Co. [10 May2000]**

"Yamanouchi Pharmaceutical Co Ltd (YP) and Warner-Lambert Co (WL) formed a strategic alliance to manufacture and wholesale *Lipitor* tablets, a lipid-loweing agent, in Japan. Lipitor was developed by WL and was co-promoted by YP in Japan" (emphasis mine). – *SDC*

https://www.marketwatch.com/story/astellas-japan-license-for-lipitor-to-run-to-2021-2012-03-28
*"Astellas*: Japan license for *Lipitor* to run to *2021*
Published: Mar 28, 2012 10:35 p.m. ET
TOKYO (MarketWatch) -- Astellas Pharma Inc. (4503.TO) said Thursday it has reached an agreement to extend its contract to sell Pfizer Inc.'s PFE, +1.43% cholesterol drug Lipitor in Japan until March 2021 from 2016.
The drug maker said in a statement it will initially pay Pfizer a sum of Y1 billion. The two firms also agreed to extend their co-promotion agreement until November 2013" (emphasis mine).

My conclusion: Note that Pfizer acquired Warner-Lambert Co., in 2000 (my research on acquisitions). The correct ultimate parent of Warner-Lambert is Pfizer, and I corrected it.Yamanouchi and Pfizer had an alliance from 2002 to 2004. Yamanouchi and Fujisawa merged to form Astella in 2005 (my research on acquisitions). Astella and Pfizer had an alliance in 2005. Unlike case 5, alliance continued after the merger.

**Case 7: Vical, Inc., and Merck & Co, Inc. [04 May1994]**

"Merck & Co and Vical Inc entered into an agreement which stated that Vical Inc granted Merck & Co an exclusive license for the use of Vical Inc's gene technology used in the treatment of tuberculosis. Under the terms of the agreement, Merck also exercised its options to license Vical's technology to integrate two vaccine targets, hepatitis C and human papiloma viruses. The agreement stated that Merck extended its exclusive option for Vical's technology to integrate with viral vaccine targets, hepatitis B and herpes simplex. Merck & Co was required to exercise its remaining options with Vical by mid-1995 for hepatitis B and herpes and by mid-1996 for Vical's tuberculosis {TB} vaccine. On May 1, 1995, Merck exercised its remaining three options to Vical's *naked DNA vaccine technology*. The agreement stated that Merck & Co paid a total of $3.0 mil US for licensing fees and option rights. The agreement also stated that Vical Inc would receive milestone payments and royalties licensed vaccine-related products developed by Merck & Co" (emphasis mine). - *SDC*

http://www.wikinvest.com/stock/Vical_(VICL)/Merck
"These excerpts taken from the VICL 10-K filed Mar 3, 2009.
Merck
In *2003*, the Company amended the agreement, providing Merck options for rights to use the Company's core DNA delivery technology for three cancer targets. In addition, Merck returned rights to the Company for Certain infectious disease vaccines. Merck has

retained rights to use the licensed technology for HIV, hepatitis C virus, and hepatitis B virus. In *June 2005*, Merck exercised options related to three cancer targets that were granted under the 2003 amendment" (emphasis mine).

My conclusion: Vical and Merck partnership lasted at least till 2005, the last year of my observation.

**STEP 4: WAS THE DRUG OR CLINICAL TRIAL DISCONTINUED? FURTHER CHECK FOR ANY EXTENSION OR NEW ALLIANCE BETWEEN THE TWO PARTNERS. IN CASE OF A NEGATIVE, USE THE DISCONTINUITY DATE AS THE TERMINATION DATE; ELSE USE THE FINAL ALLIANCE ENDING DATE. FIVE EXEMPLARS (CASES) (TERMINATION DATES WERE FOUND FOR 2.37% OF THE CASES)**

**Case 1: American Home Products, Corp., and Eisai & Co., Ltd. [01 Oct 1991]**

"American Home Products Corp and Eisai Co., Ltd formed a joint marketing venture with American Home Products owning 50.1% and Eisai owning the rest. The new company, Wyeth-Eisai Co. Ltd., was to develop pharmaceutical and nutritional products made by American Home Products. American Home Products would provide the venture with marketing and clinical development personnel, while Eisai was to handle management. Both companies were to contribute $7.4 million to the new company. The new company expected first year sales to reach $74.1 million." - *SDC*

"HD Eisai, American Home to establish joint firm
WC 103 words
PD 11 September 1991
SN Agence France-Presse
SC AFPR
LA English
CY (Copyright 1991)" - *Factiva*

http://www.eisai.com/news/news199601.html
"March 1, 1996
AHP and Eisai End their Joint Venture Partnership
…AHP will purchase Eisai's shares Wyeth-Eisai (49.99%) … today (March 1, *1996*).
… Although the joint venture partnership is ending, AHP and Eisai will maintain an amicable relationship" (emphasis mine).

My conclusion: AHP and Esai ended their JV in 1996. I further validate whether new alliances were formed between the two.

http://www.eisai.com/news/news199705.html
*"March 5, 1997* - Eisai Co., Ltd. of Tokyo (President and CEO: Haruo Naito) today announced that Wyeth-Ayerst, a subsidiary of American Home Products Corporation, filed a new drug application with the Mexican Ministry of Health on January 17, 1997 for Eisai's new Alzheimer's disease treatment, *donepezil* hydrochloride or E2020 under the trademark of *ERANZ(TM)* in Mexico.

In *February 1995*, Eisai Co., Ltd. concluded a license agreement with American Home Products Corporation for E2020, an Alzheimer's disease treatment in *Latin America*. Applications for registration in other major Latin American countries will be submitted later this year by Wyeth-Ayerst" (emphasis mine).

My conclusion: Even though the J.V. ended in 1996, AHP and Esai are still partners because of the other existing relationship about donepezil or Eranz that started in 1995 and existed at least till 1997.

"HD Alzheimer's Exelon Patch Enters Costa Rican Pharma Market
BY Denise Claux
WC 282 words
PD *23 February 2009*
SN Global Insight Daily Analysis
SC WDAN
LA English
CY Copyright 2009, Global Insight Limited. All Rights Reserved.
LP
As reported by La Nacion, Exelon was introduced last year as an oral medication in the form of pills in *Costa Rica*, where Reminyl (galantamine; Shire, U.K.) and *Eranz (donepezil; Wyeth, U.S.)* are also available" (emphasis mine). - *Factiva*

My conclusion: AHP and Esai relationships continued at least till 2005 because Wyeth (new name of AHP) was responsible for Esai's Eranz in Costa Rica up until 2009.

**Case 2: Genentech, Inc., and SmithKline Beecham Biologicals, S.A., (SmithKline Beecham P.L.C.) [31Dec1989]**

"Genentech granted SmithKline Beecham Biologicals a license for its *herpes vaccine*." - *SDC*

"Herpes simplex glycoprotein vaccine - GlaxoSmithKline – AdisInsight"
http://adisinsight.springer.com/drugs/800006502
"The vaccine, Simplirix™, was originally developed by Genentech, but was licensed to SmithKline Beecham (now GSK) for development *outside Japan*" (emphasis mine).

My conclusion: Further check Simplirix.

http://adisinsight.springer.com/drugs/800006502
"Herpes simplex glycoprotein vaccine – *GlaxoSmithKline*
Originator *Genentech*
Developer *GlaxoSmithKline*; National Institute of Allergy and Infectious Diseases
Class Protein-vaccines; Viral vaccines
Highest Development Phases
Discontinued *Herpes simplex* virus infections
Most Recent Events
30 Sep 2010 Discontinued - Phase-III for Herpes simplex virus infections in *Canada* (IM)
30 Sep 2010 Discontinued - Phase-III for Herpes simplex virus infections in European Union (IM)
30 Sep 2010 Discontinued - Phase-III for Herpes simplex virus infections in USA (IM)" (emphasis mine).

My conclusion: The relationship continued till 2010, hence, at least till 2005. Roche acquired Genentech in 1990 (my research on acquisitions).Thus, SmithKline Beecham and Genentech had an alliance in 1989. SmithKline Beecham and Roche had an alliance from 1990 to 1999. SmithKline Beecham and Glaxo Wellcome PLC merged to form GlaxoSmithKline in 2000 (my research on acquisitions). GlaxoSmithKline and Roche had an alliance from 2000 at least till 2005.

**Case 3: Mylan Laboratories, Inc., and Grupo Ferrer Internacional, S.A., [20 Apr1993]**

"Mylan Laboratories received an exclusive license from Ferrer Internacional for all rights to Ferrer's patented Dotarizine for the *United States* and Canada. Mylan was responsible for developing the drug in North America and had the right of first refusal on all derivatives of *Dotarizine*" (emphasis mine). - *SDC*

http://adisinsight.springer.com/drugs/800003533
*"Dotarizine*
Originator *Ferrer*

Developer Azwell; *Ferrer*; Kayaku; *Mylan Laboratories*
Class Antimigraines; Piperazines
Highest Development Phases
Discontinued Migraine; Stroke; Vertigo
Most Recent Events
*18 Jan 2001*Discontinued-II for Migraine in *USA* (Unknown route)
18 Jan 2001Discontinued-III for Migraine in Switzerland (Unknown route)
18 Jan 2001Discontinued-preregistration for Migraine in Spain (Unknown route)" (emphasis mine).

My conclusion: The relationship between Mylan and Ferrer ended in 2001. Based on further search, no new relationship was formed.

**Case 4: Synsorb Biotech, Inc., and Takeda Pharmaceutical Co., Ltd., [29 Nov 1996]**

"Synsorb Biotech Inc granted Takeda Chemical Industries Ltd an exclusive license to develop manufacture, and market Synsorb's Synsorb PK therapeutic in Japan. Under the terms of the agreement, the *Synsorb PK* application was a preventative therapeutic used in the treatment of Hemohytic Uremic Syndrome, a serious complication which resulted from *E. Col infections*, commonly known as "Hamburger disease" in North America. Synsorb Biotech would receive a licensing fee of $3 mil US (40.83 mil Japanese yen) and an undisclosed amount of milestone payments from Takeda Chemical. Additionally, Takeda was to provide all pre-clinical and clinical trial expenses in Japan" (emphasis mine). - *SDC*

"HD Synsorb Biotech Begins Phase III SYNSORB Trial In Japan
WC 254 words
PD 13 June 1997
ET 12:06 PM GMT
SN Dow Jones News Service
SC DJ
LA English
CY (Copyright (c) 1997, Dow Jones & Company, Inc.)
LP
CALGARY, June 13 /CNW/ - Synsorb Biotech Inc. (T.SYB) said it has begun a multi-center Phase III clinical trial in Japan sponsored by its corporate partner, Takeda Chemical Industries Ltd., for its SYNSORB Pk product…

TD
Synsorb said that, at current enrollment levels, both the Japanese and North American trials are expected to be completed by *the end of 1997*" (emphasis mine). - *Factiva*

My conclusion: The relationship between Synsorb and Takeda lasted at least till 1997.

"HD oligosaccharide matrix complex Takeda clinical data
WC 111 words
PD 7 September 1998
SN R & D Focus Drug News
SC RDFN
PG N/A
VOL ISSN: 1350-1135
LA English
CY Copyright 1998 Gale Group Inc. All rights reserved.
LP
Takeda has released preliminary results from a phase III trial completed in Japan, which demonstrate that SYNSORB Pk can be safely coadministered with antibiotics in children infected with verotoxigenic Escherichia coli (E coli O157:H7). The open label trial was conducted June-November 1997 following an outbreak of E coli O157:H7 in Japan, and the full trial results will be presented by the company in *November 1998. Phase III trials with this agent are being conducted in the USA, Canada and Argentina by SYNSORB Biotech*" (emphasis mine). - *Factiva*

My conclusion: The relationship between Synsorb and Takeda lasted at least till 1998. Also note that trials in other countries such as Canada are conducted by Synsorb alone and with Takeda in Japan.

"HD Synsorb Biotech Inc - Results from Japanese Synsorb-Pk study
WC 746 words
PD 23 November 1998
SN Canada Stockwatch
SC CNSW
LA English
CY (c) 1998 Canjex Publishing Ltd.
LP
Mr. David Cox reports
Synsorb Biotech has received the results from an open-label clinical study of Synsorb Pk (TAK-751S in Japan) co-administered with antibiotics. The study *was* part of a global

effort focused on the development of Synsorb Pk…(including E. coli O157:H7).
TD
The study was sponsored and conducted by the companies Japanese marketing and distribution partner for Synsorb Pk, Takeda Chemical Industries Ltd. … The study was carried out in Japan from June 1997 to *February 1998*" (emphasis mine). - *Factiva*

My conclusion: The relationship between Synsorb and Takeda ended in 1998 because the study is over and I do not find evidence of any new relationship or extensions based on my search.

"HD SYNSORB Biotech Inc. Announces Outcome Of Interim Analysis of SYNSORB Pk Phase III Trial
WC 885 words
PD 12 July 2000
ET 08:55 PM GMT
SN Business Wire
SC BWR
LA English
CY (Copyright (c) 2000, Business Wire)
LP
CALGARY, Alberta--(BUSINESS WIRE)--July 12, 2000--SYNSORB Biotech Inc. (Nasdaq:SYBB)(TSE:SYB.) today announced the outcome of an interim analysis of the SYNSORB Pk(R) Phase III trial….
In the overall patient population of 526 children treated within 5 days of the onset of symptoms, the data showed a limited trend toward efficacy, and *did not* successfully meet the defined protocol objectives" (emphasis mine). - *Factiva*

My conclusion: I further checked and find that even the trials conducted by Synsorb in Canada failed and did not go further, further validating my termination argument.

**Case 5: Serono International, S.A., and Amgen, Inc., [13 Nov2002]**

"Serono SA (SS) and Amgen Inc (AI) formed a strategic alliance whereby AI granted SS license for its multiple sclerosis drug *Novantrone*. Financial terms were not disclosed" (emphasis mine). - *SDC*

https://www.ftc.gov/news-events/press-releases/2002/07/resolving-anticompetitive-concerns-ftc-clears-16-billion
"Resolving Anticompetitive Concerns, FTC Clears $16 Billion Acquisition of Immunex Corp. By Amgen Inc.

Companies Required to Implement Divestiture and Licensing Remedies in Three Biopharmaceutical Markets
July 12, 2002
Under the terms of a proposed consent agreement announced today, the Federal Trade Commission would allow Amgen Inc.'s (Amgen) proposed $16 billion acquisition of Immunex Corporation (Immunex) to proceed….The order also would require the companies to grant a license to certain intellectual property rights related to TNF inhibitors to Serono S.A. (Serono)…"

http://www.wikinvest.com/stock/OSI_Pharmaceuticals_(OSIP)/Novantrone
"OSI Pharmaceuticals (OSIP)
This excerpt taken from the OSIP 10-K filed Mar 1, 2007.
Novantrone
… We market and promote Novantrone for these approved oncology indications in the United States pursuant to a co-promotion agreement with an affiliate of Merck Serono, S.A. signed in March 2003. We receive commissions from Merck Serono on net oncology sales in this market. The patent for Novantrone expired in *April 2006*, which resulted in the loss of market exclusivity for Novantrone. Following the patent expiration, we experienced an anticipated significant decrease in our commissions related to Novantrone as a result of a large decrease in oncology sales due to generic competition. Under our agreement with Merck Serono, we are also no longer obligated to pay fees associated with the sales and marketing of Novantrone" (emphasis mine).

My conclusion: The relationship between Serono and Amgen existed at least till 2005, my last period of observation because the Novantrone patent expired in April 2006, and MerckSerono still had rights as evidenced in OSI Pharmaceuticals 10K.

**STEP 5.1: IS THE ALLIANCE FORMATION MENTIONED IN SEC OR FACTIVA?**
**IN SEC, TRACK THE ALLIANCE EACH YEAR TILL NO MENTION EXISTS. CHECK FOR FURTHER ALLIANCE EXTENSIONS BETWEEN TWO ALLIANCE PARTNERS. IN CASE OF NEGATIVE, USE THE "NO MENTION" DATE AS THE TERMINATION DATE. FOUR EXEMPLARS (CASES) (4.22% OF THE CASES)**

**Case 1: Ortho Diagnostic Systems, Inc., and Corvas, Inc. [01 Jul 1992]**

"Ortho Diagnostics, a division of Johnson and Johnson, and Corvas International agreed to extend their 1991 co-development agreement to a worldwide licensing agreement.

Under the new agreement, Ortho agreed to manufacture and distribute prothrombin time (PT) blood clotting tests that incorporated Corvas' recombinant human tissue factor (rTF). In addition, Corvas agreed to produce rTF for Ortho in exchange for licensing fees and royalties expected to total $1.5 million through 1995. Corvas held an exclusive license for in vitro diagnostic usage of rTF from the Scripps Research Institute." - *SDC*

https://www.sec.gov/Archives/edgar/data/882100/0001019687-99-000151.txt
"CONFORMED PERIOD OF REPORT: 19981231
COMPANY CONFORMED NAME: CORVAS INTERNATIONAL INC
In November *1998*, the Company entered into exclusive license agreements with two affiliates of Johnson & Johnson, Ortho-Clinical Diagnostics Inc.…These agreements …supercede earlier *agreements entered in June 1992*" (emphasis mine).

My conclusion: The relationship existed at least till 1998.

http://www.getfilings.com/o0001019687-00-000326.html
"For the fiscal year ended December 31, 1999
CORVAS INTERNATIONAL, INC.
In November 1998, we entered into license agreements with two affiliates of Johnson & Johnson, Ortho-Clinical Diagnostics Inc. and LifeScan, Inc.…The new agreements continue to provide for royalties to be paid based on unit sales of tissue factor."

My conclusion: The relationship existed at least till 1999.

http://www.getfilings.com/o0001019687-01-000430.html
"For the fiscal year ended December 31, 2000
Net product sales attributable to affiliates of Johnson & Johnson for the year ended December 31, 1998 were $26,000. The *agreements continue* to provide for royalties to be paid based on unit sales of tissue factor" (emphasis mine).

My conclusion: The relationship existed at least till 2000.

http://www.getfilings.com/o0001019687-02-000466.html
"For the fiscal year ended December 31, 2001
Revenues from royalties of $117,000, $167,000 and $190,000 were recognized in 2001, 2000 and 1999, respectively, associated with license agreements with two Johnson & Johnson subsidiaries for sales of recombinant tissue factor."

My conclusion: The relationship existed at least till 2001.

http://www.getfilings.com/o0001019687-03-000502.html
"For the fiscal year ended December 31, 2002
These agreements continue to provide for royalties to be paid to the Company based on unit sales of tissue factor. For the years ended December 31, 2002, 2001 and 2000, these royalties amounted to $142,000, $117,000 and $167,000, respectively."

My conclusion: The relationship existed at least till 2002.

http://www.getfilings.com/o0001019687-03-000945.html
"For the quarterly period ended March 31, 2003
FORM 1O-Q
My conclusion: The relationship between Johnson & Johnson and Corvas ended in 2003 because neither the agreement nor J&J finds mention in the filings of Corvas. Also, according to Bloomberg, Corvas went out of business in October 2005."

**Case 2: Human Genome Sciences, Inc., and MedImmune, Inc. [31 Jul 1995]**

"Human Genome Sciences Inc(HGS) and MedImmune Inc formed a joint venture to develop and commercialize anti-infective agents which used the genetic structures of infectious microbes. Under the terms of the agreement, HGS was to supply the bacterial genomes for the joint venture. MedImmune was to be responsible for the development and commercialization of products produced by the joint venture. The partners were to initially focus on the development of vaccines and antibody-based drug products. No financial details were disclosed." - *SDC*

https://www.sec.gov/Archives/edgar/data/901219/000095013306001228/0000950133-06-001228.txt
"CONFORMED PERIOD OF REPORT: *20051231*
COMPANY CONFORMED NAME: HUMAN GENOME SCIENCES INC
We entered into a collaboration and license agreement with MedImmune in July 1995, which we amended in March and December 1997...We are entitled to a portion of the payments received by MedImmune under its sub-license...Through 2003, we have received $1.1 million from MedImmune."

My conclusion: The relationship between MedImmune and Human Genome Sciences lasted at least till 2005 because Human Genome received payments till 2003 and the alliance is still discussed in the annual report for the 2005 period. But I check further.

https://www.sec.gov/Archives/edgar/data/901219/000095013307000843/0000950133-07-000843.txt
"CONFORMED PERIOD OF REPORT: 20061231
COMPANY CONFORMED NAME: HUMAN GENOME SCIENCES INC
The Company has entered into a number of other agreements. These include agreements with…MedImmune, Inc. and others."

My conclusion: The relationship between MedImmune and Human Genome Sciences lasted at least till 2005 and the link above further recognizes the ongoing nature of collaboration with Medimmune.

**Case 3: T Cell Sciences, Inc., and Astra, A.B. [06 Nov 1991]**

"T Cell Sciences, Inc. and Astra AB signed an agreement to develop and market therapeutic products that result from T Cell Sciences' antigen receptor(*TCAR) technology*. The partners were to develop monoclonal antibodies and protein-derived immunomodulators, which are recombinantly produced proteins identical to certain T cell antigen receptor regions on T cells, that have efficacy in treating autoimmune diseases such as rheumatoid arthritis, *multiple sclerosis*, Crohn's disease and sarcoidois. The partners disclosed their goal was to use the antibody and immunomodulator products to activate the immune system to eliminate specific T cells implicated as casual agents in autoimmune diseases. The agreement called for Astra to invest US$15 mil over the initial *two years*, with another US$17 mil invested by Astra pursuant to options over the duration after the first two years. The agreement also stipulated T Cell Sciences will be the sole supplier of the products. Both partners have signed an amended agreement, in which Astra reaffirmed its original funding and has agreed to increase its commitment to the program by assuming responsibility from T Cell Sciences for future development and manufacturing of two monoclonal antibodies, *TM27* and TM29" (emphasis mine). - *SDC*

http://www.prnewswire.com/news-releases/t-cell-sciences-announces-progress-in-phase-i-multiple-sclerosis-trial-with-astra-ab-76852102.html
"T Cell Sciences Announces Progress in Phase I Multiple Sclerosis Trial with Astra AB
*Feb 23, 1998*, 00:00 ET from T Cell Sciences, Inc.
NEEDHAM, Mass., Feb. 23 /PRNewswire/ -- T Cell Sciences, Inc.
(Nasdaq: TCEL) today announced positive progress from a Phase I clinical trial of the humanized monoclonal antibody, ATM027, in patients with multiple sclerosis. *ATM027*,

which has been exclusively licensed by Astra AB, is one of the products derived from the Company's T Cell Antigen Receptor *(TCAR)* program" (emphasis mine).

My conclusion: The relationship between T Cell Sciences, Inc. and Astra AB lasted at least till 1998

http://media.corporate-ir.net/media_files/irol/93/93243/reports/199910k.pdf
"FORM 10-K
For the fiscal year ended December 31, 1999
AVANT IMMUNOTHERAPEUTICS, INC.
(f/k/a T Cell Sciences, Inc.)
In early 1992, we entered into a joint development program with AstraZeneca plc ("Astra") to develop products resulting from our proprietary TCAR technology….The original agreement was modified in 1993 with Astra...By the end of 1995, we had received substantially all of the original funding payments. In 1996, we amended the agreement with Astra to transfer some of our rights to the TCAR technology, including two therapeutic products, ATM-027 and ATP-012, to Astra, which is solely responsible for further clinical development and commercialization. Under the amended agreement, we could receive royalties from product sales, as well as milestone payments which may total up to $4 million as specific clinical milestones are achieved. In 1997, we received a milestone payment from Astra because one of the products derived from our TCAR program entered clinical trials for the treatment of multiple sclerosis. In 1998, Astra announced that Phase I data from these trials had shown an effect on the target cells and that there had been no serious adverse effects in the study to date, and initiated a Phase II study. *In 1999,* we announced results of the Phase II study of the TCAR monoclonal antibody (ATM-027) being developed by Astra for the treatment of multiple sclerosis. The results showed that ATM-027 was safe and well tolerated, however, in the view of Astra the reduction of disease activity in the study population did not reach a level that would be of value for those patients. Therefore, *Astra made the decision to stop further development of ATM-027* for multiple sclerosis *but is reviewing development of the TCAR peptide, ATP-012,* as a vaccine for multiple sclerosis under the terms of the TCAR agreement" (emphasis mine).

My conclusion: The relationship between T Cell Sciences and Astra AB ended in 1999 because Astra stopped the development and none of the annual reports of Avant ever mention Astra. Note that T Cell merged with Virus Research in 1998 to form Avant Immunotherapeutics Inc. Also, Astra merged with Zeneca to form AstraZeneca in 1999. Thus, the alliance between T Cell Sciences and Astra lasted from 1991 to 1997. Avant and Astra allied in 1998, and Avant and AstraZeneca in 1999.

**Case 4: IVAX, Corp., and SS Pharmaceutical Co., Ltd. [01 Apr 1991]**

"Ivax Corp and SS Pharmaceutical Co. signed a series of licensing agreements whereby Ivax subsidiaries licensed SS Pharmaceutical's anti-inflammatory drug (unspecified) and SS Pharmaceuticals received rights to market Ivax's nalmefene. In exchange for an up-front license fee and royalties on sales, SS Pharmaceutical Co. had exclusive rights to oral nalmefene in Japan and Korea. Ivax subsidiary, Baker Cummins was to market SS Pharmaceutical's anti-inflammatory drug in North America, and another Ivax subsidiary, Waterford, was to distribute the product in the UK, Ireland, Israel, Iran, and certain parts of Africa. Ivax and SS. became R&D partners in 1989. SS. owns 3.3% of Ivax outstanding shares." - *SDC*

"HD Ivax acquisitions, not development, pay the way
BY By David Poppe
WC 2401 words
PD 5 February 1993
SN Miami Review
SC MIAM
In 1988, when Ivax was barely more than a concept, Japanese drug maker SS Pharmaceutical Co. invested nearly $12 million and Schiapperelli Corp., an Italian company, invested $10 million. Both investments have more than quadrupled in five years." - *Factiva*

My conclusion: The relationship between Ivax Corp and SS Pharmaceutical started in 1988 (I fix this in the dataset) and lasted at least till 1993.

http://www.getfilings.com/comp/k0000772197.html
I note that none of the annual reports mention SS or Japan

My conclusion: The relationship between Ivax Corp and SS Pharmaceutical lasted from 1988 to 1994 because none of the filings from 1995 to 2005 mention SS or Japan. Also, there is no news in Factiva about the relationship after 1993.

**STEP 5.2: IS THE ALLIANCE FORMATION MENTIONED IN SEC OR FACTIVA? IN FACTIVA, TRACK THE ALLIANCE EACH YEAR TILL NO MENTION EXISTS. CHECK FOR FURTHER ALLIANCE EXTENSIONS BETWEEN TWO ALLIANCE PARTNERS. IN CASE OF NEGATIVE, USE THE "NO MENTION" DATE AS THE TERMINATION DATE. FOUR EXEMPLARS (CASES) (5.56% OF THE CASES)**

**Case 1: Enzon, Inc., and Emisphere Technologies, Inc. [09 Jul 1992]**

"Enzon, Inc. and Emisphere Technologies, Inc. signed an agreement to jointly develop orally administered pharmaceutical products. The collaboration focused on combining proteins modified through Enzon's Pegnology drug delivery technology, which reduces the quantity and frequency of doses and lowers the allergic reactions of proteins used as therapeutic agents, and Emisphere's Oral Drug System technology, which shields therapeutic agents by encapsulating them in microspheres composed of amino acids. The products that are developed as a result of the collaboration are expected to last longer in the bloodstream, have protection from gastrointestinal acids, and exhibit fewer allergic reactions." - *SDC*

"HD Emisphere FY 92 Results
WC 132 words
PD 1 November 1992
SN Applied Genetics News Business Communications Company, Inc.
SC AGNW
VOL Vol. 13, No. 4 ISSN: 0271-7107
LA English
CY COPYRIGHT 1992 by Business Communications Company, Inc.
LP
Emisphere Technologies, Inc. reports total revenues for its complete fiscal year ended July 31, 1992...The company…has development agreements with The Upjohn Company, Sandoz Pharmaceutical, Schering-Plough, *Enzon* and J3 Biologics" (emphasis mine). - *Factiva*

My conclusion: The relationship between Enzon and Emisphere was at least till July 31 1992. Note the Emisphere lists firm names with development agreements.

"HD EMISPHERE REPORTS 1993 4TH QUARTER AND YEAR END RESULTS
WC 602 words
PD 21 October 1993
SN PR Newswire
SC PRN
LA English

CY (Copyright (c) 1993, PR Newswire)
HAWTHORNE, N.Y. Oct. 21 /PRNewswire/ -- Emisphere Technologies, Inc. (NASDAQ: EMIS) today reported financial results for the fourth quarter and year ended July 31, 1993…The company has development agreements with a number of companies, including The Upjohn Company(NYSE: UPJ), Schering-Plough Corporation(NYSE: SGP) and *Enzon*, Inc.(NASDAQ-NMS: ENZN)" (emphasis mine). - *Factiva*

My conclusion: The relationship between Enzon and Emisphere was at least till July 31 1993. Note the Emisphere lists firm names with development agreements and Enzon is there.

"HD EMISPHERE REPORTS FIRST QUARTER FISCAL 1994 RESULTS
WC 466 words
PD 8 December 1993
SN PR Newswire
SC PRN
LA English
CY (Copyright (c) 1993, PR Newswire)
LP
HAWTHORNE, N.Y., Dec. 8 /PRNewswire/ -- Emisphere Technologies, Inc. (NASDAQ: EMIS) today reported financial results for the first quarter of fiscal 1994 ended *Oct. 31, 1993*…The company has development agreements with a number of companies, including The Upjohn Company and the Schering-Plough Corporation" (emphasis mine). - *Factiva*

My conclusion: The relationship between Enzon and Emisphere ended on October 31, 1993. Note the Emisphere lists firm names with development agreements and Enzon is not there now. I further validate it from the news below.

"HD Organogenesis Optimistic About Skin Product
WC 316 words
PD 1 January 1994
SN Applied Genetics News Business Communications Company, Inc
SC AGNW
VOL Vol. 14, No. 6 ISSN: 0271-7107
LA English
CY Copyright 1994 Business Communications Company, Inc.
Emisphere (Hawthorne, NY) reports revenues in the quarter ended October 31, all of which came from R&D contracts, of $85,000, but a net loss of $1.6 million. The company hopes its research investment in an oral drug delivery system will pay off, as do its backers, Schering-Plough and Upjohn." - *Factiva*

My conclusion: Further confirms the alliance is gone because Enzon does not find any mention.

**Case 2: Monoclonal Antibodies, Inc., and Fujirebio, Inc. [01 Mar1988]**

"Fujirebio Inc licensed Monoclonal Antibodies Inc's allergy and autoimmune diagnostics product line." - *SDC*

"HD CEO Interview QUIDEL CORP. (QDEL)
WC 6576 words
PD 26 October 1992
SN The Wall Street Transcript
SC TWST
VOL Vol. CXVIII, No. 04
LA English
CY (Copyright 1992)
LP
QUIDEL CORPORATION (QDEL)
We made the acquisition of Cytotech in 1989 followed by a *merger with Monoclonal Antibodies, Inc. in January 1991*. We're very happy with the business in Japan and *our ventures with Fujirebio, Inc.* and Takeda Pharmaceuticals, but we believe that we can grow in the European market with our own presence" (emphasis mine). - *Factiva*

My conclusion: Quidel acquires Monoclonal in 1991 and continues its alliance with Fujirebio.

"HD QUIDEL FILES FOR FDA MARKETING CLEARANCE FOR RAPID FECAL OCCULT BLOOD TEST
WC 388 words
PD 1 April 1993
SN Biotech Business Worldwide Videotex
SC BTBU
VOL Vol. 6, No. 4
LA English
CY COPYRIGHT 1993 Worldwide Videotex
LP
QUIDEL Corporation (NASDAQ: QDEL), of San Diego, CA, has filed a 510(k) submission with the U.S. Food and Drug Administration...We are pleased to have developed this test in conjunction with our Japanese partner, Fujirebio, Inc. and look forward to their successful market launch In Japan while we market the test in the United States and Europe through our own professional sales force and distribution network." - *Factiva*

My conclusion: Quidel's alliance with Fujirebio lasted at least till 1 April 1993. I impute 1993 is the end date for two reasons. First, I do not find any relevant news after this year. Second, I find that, on an average, if the acquirer is not interested in continuing the alliance initiated by the acquired party it does so within one to two years. Thus, I believe

Monoclonal Antibodies Inc and Fujirebio Inc had partnership from 1988 to 1990 and Quidel and Fujirebio Inc from 1991 to 1993. I further try to validate this as shown below.

https://www.sec.gov/Archives/edgar/data/353569/0000936392-97-000871.txt
I note that the1997 10k does not mention Fujirebio.

http://www.prnewswire.com/news-releases/quidels-quickvuer-influenza-test-launched-in-japan-73581357.html
"Quidel's QuickVue(R) Influenza Test Launched in Japan
Oct 10, 2001, 01:00 ET from Quidel Corporation
SAN DIEGO, Oct. 10 /PRNewswire/ -- Quidel Corporation (Nasdaq: QDEL), a leading provider of rapid point-of-care (POC) diagnostic tests, today announced that its QuickVue(R) Influenza test product is now being sold throughout Japan by the Company's exclusive Japanese distributor, Sumitomo Seiyaku Biomedical Co., Ltd., ..."

My conclusion: I find that the exclusive distributor for Japan is Sumitomo not Fujirebio for Quidel's QuickVue(R) further confirming my suspicion that Quidel changed the distributor.

**Case 3: Lidak Pharmaceuticals, Inc., and Chiron, Corp. [15 Apr 1992]**

"Lidak Pharmaceuticals, Inc. and Chiron Corp. signed an agreement to jointly develop and test potentially new immune therapies against AIDS. The agreement was based on Lidak's proprietary human immune system-reconstituted severe combined immune deficiency(SCID) mouse technology. In this process, mice with SCID are grafted with mature human peripheral blood cells to create hu-PBL-SCID mice. The grafted human cells make the mice susceptible to HIV infection, and useful in the testing of ant-AIDS compounds. Chiron contributed its proprietary vaccines directed against certain properties of HIV." - *SDC*

"HD Corporate Activities (Part 5 of "Review of 1992")
WC 1071 words
PD 1 January 1993
SN Antiviral Agents Bulletin Biotechnology Information Institute
SC AVAB
VOL Vol. 6, No. 1
LA English
CY COPYRIGHT 1993 by Biotechnology Information Institute
LIDAK Pharmaceuticals raised capital for development of LIDAKOL, a long-chain alcohol formulation, for treatment of herpes, HIV and other indications. LIDAK formed a collaboration with Chiron Corp. for testing of Chiron's HIV vaccines in the company's hu-PBL-SCID immune deficient mice with reconstituted human immune systems." - *Factiva*

My conclusion: Lidak and Chiron collaborated at least till 1993. I believe the collaboration ended in 1993 because I do not find any news of the collaboration after that. I further searched for relevant news and find Lidak tied up with an Israeli firm in 1993 and Chiron halted the application for vaccine approval in 1996.

"HD News Capsule
WC 484 words
PD 1 August 1993
SN Applied Genetics News Business Communications Company, Inc.
SC AGNW
VOL Vol. 14, No. 1 ISSN: 0271-7107
LA English
CY COPYRIGHT 1993 by Business Communications Company, Inc.
Lidak (La Jolla, CA) says its topical anti-herpes drug candidate, LIDAKOL, has completed a Phase II pilot study. The antiviral agent in the product is docosonol. The company has licensed the product to *CTS Chemical Industries* (Kiryat Malachi, Israel) for manufacture and marketing in Israel" (emphasis mine). - *Factiva*

http://www.bioinfo.com/aabtext.html
"December 1996 Antiviral Agents Bulletin news stories
Herpes Simplex Virus Subunit Vaccine Development Halted by Chiron
Chiron Corp. (Emeryville, CA) has announced that it has *halted* development of its bivalent recombinant herpes simplex virus type 2 (HSV-2) subunit vaccine after preliminary data from Phase III clinical trials for genital herpes prophylaxis failed to indicate efficacy for this product. Chiron *will not apply* for approval of the vaccine" (emphasis mine).

**Case 4: Cortecs, Ltd., and Roche Holding, A.G. [31 Aug 1990]**

"Cortecs and Roche formed a strategic alliance to manufacture and develop an oral form of Roche's Roferon as a potential treatment for AIDS-related Kaposi's Sarcoma, hairy-cell leukemia, chronic hepatitis, colorectal cancer, and lung cancer. Under the agreement, Cortecs was to manufacture the final products using its Macromol delivery system. The system prevented the breakdown of the drug by the digestive system with a "water-in-oil" microemulsion. Cortecs was to retain manufacturing rights once the product was commercialized." - *SDC*

"HD HOFFMAN, WESTERN CAPITOL AND CORTECS FORM VENTURE FOR RESEARCH INTO ORAL FORM OF ALPHA-INTERFERON.
WC 139 words
PD 3 January 1991
SN Manufacturing Chemist
SC MCHMDI
PG 13

LA English
CY Copyright Miller Freeman 1991
LP
Preliminary studies are to be carried out by *Cortecs*, using *Roche*'s human interferon alpha-2a drug, Roferon-A, and WCL's drug delivery systems" (emphasis mine). - *Factiva*

My conclusion: Cortecs and Roche collaborated at least till 1991.

"HD F HOFFMAN-LA ROCHE AND CORTECS LIMITED ORAL ALPHA-INTERFERON ANNOUNCEMENT
WC 128 words
PD 27 February 1991
SN PR Newswire
SC PRN
LA English
CY (Copyright (c) 1991, PR Newswire)
LP
LONDON, Feb. 27 /PRNewswire/ -- Cortecs Limited today issued the following statement regarding a joint oral Alpha-Interferon study with Hoffman-La Roche: Following initial positive results from a joint study at the Macromolecular Clinical Research Centre in Korea, the companies are now planning a confirmatory trial in Caucasian subjects in Europe." - *Factiva*

"HD Clinical Trial Milestones (Review of 1992. Part 4 of 9)
WC 609 words
PD 1 January 1992
Cortecs Ltd. in collaboration with Hoffmann-La Roche began trials of oral liposomal-encapsulated alpha-interferon. Roche has also initiated oral interferon trials in the U.S.S.R." - *Factiva*

"HD Cortecs and Roche Halt Development of Oral Interferon
WC 138 words
PD 1 September 1992
SN Antiviral Agents Bulletin Biotechnology Information Institute
SC AVAB
VOL Vol. 5, No. 9
LA English
CY COPYRIGHT 1992 by Biotechnology Information Institute
LP
Cortecs Ltd. (Isleworth, UK) and Hoffmann-La Roche (Basel, Switzerland) have *suspended* their collaborative development of oral formulations of alpha-interferon. Clinical trials in Switzerland and the U.K. *failed* to confirm the positive results reported from an earlier trial conducted by the Macromolecular Clinical Research Centre (Korea) which had reported that lipid-encapsulated orally administered interferon could pass

through the stomach and intestinal linings and enter the bloodstream without excessive protein digestion. Cortecs had earlier reported about 30% bioavailability and irregularities in manufacturing for the product produced in Korea. The material used in the recent clinical trials was formulated by Cortecs itself using a different production process. Cortecs and Roche may restart the oral interferon project if Cortec's oral insulin formuation shows significant bioavailability in upcoming clinical trials" (emphasis mine). - *Factiva*

My conclusion: Cortecs and Roche collaboration ended on 1 Sep 1992 because Roche suspended the collaborative development and I did not find any news about them after this.

**STEP 6.1: DID ANY OF THE PARTNERS GO BANKRUPT OR MERGE? USE THE BANKRUPTCY DATE AS THE TERMINATION DATE. FOUR EXEMPLARS (CASES) (1.32% OF THE CASES)**

**Case 1: deCode Genetics, Inc., and Elitra Pharmaceuticals, Inc. [01 Jul 2002]**

"deCODE genetics and Elitra Pharmaceuticals Inc formed a strategic alliance to provide research and development of new antibiotics to combat drug-resistant bacteria in the United States." - *SDC*

https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=27991
"November 14, 2016 6:10 AM ET
Biotechnology
Company Overview of Elitra Pharmaceuticals
Elitra Pharmaceuticals *went out of business*. Elitra Pharmaceuticals, Inc. engages in discovering, developing, and commercializing the next generation of antimicrobial drugs that target essential gene products of pathogenic organisms. Elitra *has* research collaborations with *Merck & Co.*, LG Life Sciences, bioLeads, and *deCODE genetics* to discover new antimicrobials" (emphasis mine).

My conclusion: deCODE genetics and Elitra Pharmaceuticals ended the relationship because Elitra went out of business. I further investigate below.

http://www.fiercebiotech.com/special-report/elitra-pharmaceuticals-2003-fierce-15-revisited
"Elitra Pharmaceuticals
What happened: Elitra found itself among a number of antibiotics developers struggling to stay afloat...In late *2004*, Elitra cut its workforce of about 70 and *sold its assets to Merck*. The drug giant also paid San Diego State University for the rights to the patents on which Elitra was founded" (emphasis mine).

My conclusion: deCODE genetics and Elitra Pharmaceuticals ended the relationship in 2004 because Elitra went out of business and Merck acquired its assets in 2004.

http://www.evaluategroup.com/Universal/View.aspx?type=Story&id=58645
"deCODE and Merck & Co., Inc. Form Broad Drug Development Alliance
Reykjavik, Iceland -- February 26, 2004 -- deCODE genetics (Nasdaq:DCGN) today announced the formation of a seven-year alliance with Merck & Co ., Inc. (NYSE:MRK) under which deCODE will conduct information-rich clinical trials on a range of Merck's developmental compounds."

My conclusion: Interestingly Merck which acquired Elitra's assets in 2004 broadens its alliance in 2004, further confirming that deCODE might have continued working with Elitra till Elitra went out of business.

**Case 2: Essential Therapeutics, Inc., and Fujisawa Pharmaceutical Co., Ltd. [09 Aug 2002]**

"Essential Therapeutics Inc (ET) and Fujisawa Pharmaceutical Co Ltd (FT) planned to form a strategic alliance in which ET was to utilize its technology to develop assay systems for the discovery of novel antibiotics, and was to perform high-throughput screening of the compounds in FP's library through its subcontractor. FP will conduct lead generation and lead optimization, and was to exclusively develop, manufacture and market the resulting products on a worldwide basis. ET was to retain rights to develop the compounds under certain conditions and will receive funding and potential milestone and royalty payments." - *SDC*

https://www.sec.gov/Archives/edgar/data/1010915/000092701603001554/d10k.htm
"10-K 1 d10k.htm FORM 10-K
FOR THE FISCAL YEAR ENDED DECEMBER 31, 2002
ESSENTIAL THERAPEUTICS, INC.
The employees remaining in California will either assist with the closure of certain California facilities or assist in the performance of the Company's obligations under its collaborative agreement with *Fujisawa* Pharmaceutical Co., Ltd, which is *expected to conclude in the third quarter of 2003*" (emphasis mine).

My conclusion: Essential Therapeutics and Fujisawa ended the alliance in the third quarter of 2003. I further investigated and find that Essential filed for bankruptcy in May 2003 as shown below. Also, I did not find any news pertaining to any new relationship between the companies.

https://www.myglobalbizz.com/ms/manufacture/essential-therapeutics-inc/
"ESSENTIAL THERAPEUTICS INC
In May 2003, the company and its wholly owned subsidiaries, Maret Corporation and Althexis, filed a voluntary petition for protection under *Chapter 11* of the United States Bankruptcy Code. The plan of reorganization for the company became effective in October 2003 by order of the U.S. Bankruptcy Court for the District of Delaware, and the company was renamed Trine Pharmaceuticals, Inc. in November 2003" (emphasis mine).

**Case 3: VivoRx Pharmaceuticals, Inc., and HemoCleanse, Inc. [24 Oct 1994]**

"VivoRx Pharmaceuticals Inc entered into a joint venture agreement with;HemoCleanse Inc to develop a bioartificial liver. The new joint venture firm was called HepatoCell Inc. VivoRx would contribute its cell separation and encapsulation technologies to the venture, while HemoCleanse would contribute its extracorporeal device and sorbent chemical technologies. HepatoCell would combined the technologies to create a bioartificial liver to provide artificial liver support for severe liver failure patients. HepatoCell was still in the development and clinical testing stage of the bioartificial liver. Financial details were not disclosed." - *SDC*

"HD Monsanto Licenses Artificial Liver Tech To HemoCleanse >MTC
WC 257 words
PD 10 January 1997
ET 12:05 PM GMT
SN Dow Jones News Service
SC DJ
LA English
CY (Copyright (c) 1997, Dow Jones & Company, Inc.)
LP

TD
HemoCleanse also has a joint development and marketing agreement with VivoRx Pharmaceuticals Inc. for the supply of hepatocytes for this device." - *Factiva*

My conclusion: HemoCleanse and VivoRx have an alliance at least till Jan 1997.

"HD HemoCleanse Receives Grant From the National Institutes of Health for Development of Bioartificial Liver
WC 530 words
PD 20 August 1997
ET 08:06 PM GMT
SN Business Wire
SC BWR
LA English
CY (Copyright (c) 1997, Business Wire)
LP" - *Factiva*

My conclusion: HemoCleanse and VivoRx partnership ended in Aug 1997 because the news no longer mentions VivoRx and, also, HemoCleanse ran out of funds in 17 July 1998 as shown below.

"HD Promising Purdue-based company runs out of funds
WC 559 words
PD 17 July 1998

ET 07:51 PM GMT
SN Associated Press Newswires
SC APRS
LA English
CY (c) 1998. The Associated Press. All Rights Reserved.
LP
WEST LAFAYETTE, Ind. (AP) - A biomedical company that developed a promising blood treatment for liver failure has *laid off all of its 26 employees* after running out of financing. *HemoCleanse Inc. has fallen victim*, at least temporarily, to the high costs associated with the health care industry, its top executive said" (emphasis mine). - *Factiva*

**Case 4: Alpha-Beta Technology, Inc., and IDEXX Laboratories, Inc. [22 Oct 1998]**

"Alph-Beta Technology Inc(AB) and Idexx Laboratories Inc(IL) agreed to form a strategic alliance to collaborate on the commercialization of therapeutic and diagnostic products for the veterinary, environmental and food markets. AB and IL was to co-develop products for these markets based on AB's technology. Also as part of the agreement, IL was to have exclusive marketing and distribution rights to Alpha-Beta's beta-glucan immunomoldulatory compunds and fungal detection technology. Financial terms were not disclosed." - *SDC*

"HD Alpha-Beta seeks liquidation.
WC 173 words
PD 28 January 1999
ET 11:46 PM GMT
SN Reuters News
SC LBA
LA English
CY (c) 1999 Reuters Limited
LP
WORCESTER, Mass., Jan 28 (Reuters) - Alpha-Beta Technology Inc. said Thursday it would *seek an out-of-court liquidation of assets* following its decision to *abandon its Phase III clinical trial of Betafectin PGG-glucan*, a drug designed to prevent infections in upper gastrointestinal surgery patients. The company also said its stock would be delisted from the Nasdaq Stock Market on Friday" (emphasis mine). - *Factiva*

My conclusion: Alpha-Beta Technology and IDEXX ended the alliance on 28 Jan 1999 because Alpha-Beta Technology abandoned Phase III TRIAL and was also seeking liquidation of assets.

**STEP 6.2: DID ANY OF THE PARTNERS GO BANKRUPT OR MERGE? USE THE MERGER DATE AS THE TERMINATION DATE. THREE EXEMPLARS (CASES) (5.63%OF THE CASES)**

**Case 1: Delsys Pharmaceutical, Corp., and Elan Pharmaceutical Technologies. [27 Nov 2000]**

"Delsys Pharmaceutical Corp and Elan Pharmaceutical Techologies fomed a;stratgic alliance to develop oral controlled release products. The company will also established R&D collaborations to develop solid oral dose products with Pfizer, SmithKline Beecham, and Johnson & Johnson." - *SDC*

http://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=27477
"As of September 2001, Delsys Pharmaceutical Corporation was *acquired* by Elan Corp. plc" (emphasis mine).

My conclusion: Delsys and Elan alliance that started in 2000 ended in 2001 because Elan acquired Delsys.

**Case 2: AcroMetrix, Corp., and Nabi Biopharmaceuticals. [31Jan 2003]**

"AcroMetrix Corp (AC) and Nabi Biopharmaceuticals (NB) formed a strategic alliance to manufacture and develop *ViroSure quality* control products for infectious diseases testing to clinical laboratories and blood screening organizations in the United States. NB was expected to develop and manufacture the products while AC aimed to focus on marketing and distribution services. Financial details were not disclosed" (emphasis mine). - *SDC*

http://www.prnewswire.com/news-releases/acrometrix-corporation-completes-acquisition-of-virosure-product-line-59040592.html
"AcroMetrix Corporation Completes Acquisition of Virosure Product Line
Jan 28, 2004, 00:00 ET from AcroMetrix
BENICIA, Calif., Jan. 28 /PRNewswire/ -- AcroMetrix announced today that it has completed the *acquisition of the ViroSure product line* previously manufactured by *Nabi Biopharmaceutical's* antibody business and other assets related to its diagnostics business" (emphasis mine).

My conclusion: AcroMetrix Corp and Nabi alliance ended in 2004 because AcroMetrix acquired ViroSure product line and related assets from Nabi.

**Case 3: Elan Corp., P.L.C and Rorer Group, Inc. [30 Sep 1986]**

"Elan licensed its once-daily *nifedipine* product to the Rorer Group for the United Kingdom. Nifedipine, a calcium antagonist, was used to treat angina and hypertension. Elan also licensed the product to Farmitalia Carlo Erba, Green Cross, and Pfizer" (emphasis mine). - *SDC*

http://www.prnewswire.com/news-releases/elan-announces-steps-to-consolidate-and-build-its-uk-and-irish-pharmaceutical-businesses-77671542.html
"Oct 21, 1997, 01:00 ET from Elan Corporation, plc
DUBLIN, Ireland, Oct. 21 /PRNewswire/ -- Elan Corporation, plc (NYSE: ELN)
In a separate transaction, Elan also announced that it had reached agreement with Rhone-Poulenc Rorer Limited ("RPR") to acquire Univer(R) (controlled-release verapamil) and Nifensar(R) (controlled-release *nifedipine*) for the U.K., and Nifensar for Ireland. Univer and Nifensar are products for the treatment of hypertension and angina that utilize Elan's proprietary drug delivery technologies and were *originally licensed to RPR by Elan in 1987*" (emphasis mine).

My conclusion: Elan and Rorer ended the alliance in 1997 because Elan acquired alliance related assets from Rorer. Rorer was part of Rhone-Poulenc SA in 1990 (my research on acquisitions). Hence, Elan and Rorer had an alliance from 1986 to 1989, and Elan and Rhone Poulenc had an alliance from 1990 to 1997.